GROWTH AND ITS IMPLICATIONS FOR THE FUTURE

Part 1

HEARING WITH APPENDIX

BEFORE THE

SUBCOMMITTEE ON FISHERIES AND WILDLIFE CONSERVATION AND THE ENVIRONMENT

OF THE

COMMITTEE ON MERCHANT MARINE AND FISHERIES HOUSE OF REPRESENTATIVES

NINETY-THIRD CONGRESS

FIRST SESSION

ON

THE EFFECTS NATIONAL GROWTH WILL HAVE ON RESOURCES, THE ENVIRONMENT, AND FOOD SUPPLY IN THE FUTURE

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CONTENTS

APPENDIX

FOREWORD

May 16, 1973.

To: Members of the House Committee on Merchant Marine and Fisheries.

From: John D. Dingell, chairman, Subcommittee on Fisheries, Wildlife Conservation, and the Environment.

Subject: Hearings on growth and its implications for the future.

Comprehensive declaration of policy incorporated in the National Environmental Policy Act (NEPA) illustrates the complex intertie between the concepts of economic growth and environmental protection. Section 101(a) states that it is the continuing policy of the Federal Government to maintain conditions under which this country can coexist with nature "in productive harmony" while also fulfilling the social requirements of present and future generations of Americans. In addition to this broad statement, the act sets forth certain specific national goals among which is the achievement of "a balance between population and resource use" to sustain "high standards of living and wide sharing of life's amenities."

To make sure that Federal agencies actually focus their efforts on these policy goals, section 102(a)(C) requires the preparation and public dissemination of detailed impact statements for any and all Federal activities which could significantly affect our environment. Also, section 102(2)(B) directs the Federal agencies to improve their decisionmaking approaches by developing new evaluation methodologies to insure that environmental values are given appropriate consideration, along with economic and technological factors, in key decisions.

Since the enactment of NEPA, the subcommittee has conducted extensive oversight hearings and commissioned several investigations to determine how well the various agencies are carrying out these responsibilities and mandates.

Our oversight work so far clearly shows, in my judgment, that the Federal Government has only begun to conduct full and adequate environmental assessments of growth-oriented programs and policies. A continuing, open dialog in the Congress concerning this profoundly important subject is necessary if we are to meet the social needs of our society.

While this committee's efforts are confined by our limited jurisdiction over national policies, our individual understanding of the implications of the legislation processed in each new Congress depends heavily on each committee dealing with the relationships between evolving problems, policies, and changing values.

"The Limits to Growth," which was recently published under the auspices of the Club of Rome,[1] perhaps represents the most scholarly

[1] The Club was founded by Aurelio Peccei, an internationally known Italian economist and businessman, who is vice chairman of the board of Olivetti and managing director of Italconsult, an Italian research organization. Peccei funded the Club in 1968 by inviting about 50 leading scientists, humanists, economists, planners, educators, and industrialists of different countries to join in an effort to study the problems of the future from a global standpoint. Funds for the "Limits" project were provided by the Volkswagen Foundation.

attempt of recent years to analyze the global interactions between population, resource depletion, food supply, pollution, and capital requirements. The book is based on an ambitious world modeling project carried out by the MIT Systems Dynamics Group, with the avowed purpose of demonstrating the long-term causes and consequences of growth in a finite environment.

As I understand the general findings of this study, world population is now growing much too rapidly for societies to make necessary adjustments and responses to the problems of supplying essential raw materials and of controlling environmental abuses. The authors conclude that something must be done quickly by way of balancing population and material growth if we are to avoid the undesirable consequences of approaching the physical limits of the Earth's resources.

World population is expected to double by the end of this century. In the United States alone, increasing population demands by the year 2000 will probably require the construction of additional public and private facilities equivalent to all those already in existence.

The Limits study has stimulated worldwide debate; [2] editions of the book have appeared in over 20 languages. Some critics of the project have quarreled over the technicalities of the world model used by the MIT group. Others have suggested that imperfect data used for the study made the model an inaccurate representation of the real world. Still others have argued that the pricing mechanism of our own society, continued technological advances, and value adjustments will eventually overcome environmental deficiencies.

I cannot judge whether the synthesis of facts and forecasts embodied in this vital book are accurate in all respects. But I do believe that this committee cannot escape the implications of the controversy surrounding the MIT group's efforts in the context of the policy and goals set forth in the National Environmental Policy Act.

For this reason, I felt it appropriate to recommend to our chairwoman that extensive hearings be held on the general subject with no particular legislative purpose in view. With her approval, we subsequently invited six distinguished witnesses to meet with the subcommittee in a 1-day planning session designed to assist us in laying out a detailed scenario for future hearings.

The participants in the planning session held May 1 included Russell W. Peterson, former Governor of Delaware and currently chairman of the Commission on the Third Century; Dennis L. Meadows, a principal author of *The Limits to Growth*, Dartmouth College; Robert A. Frosch, Assistant Director of the newly established United Nations Environment Programme; Lester S. Brown, senior fellow of the Overseas Development Council; Alfred Heller, president of a nonprofit educational organization, California Tomorrow; Steven Salyer, Citizens Committee on Population and the American Future; and Peter S. Hunt, president of Peter Hunt Associates.

On the evening preceding the planning session, I had the opportunity of meeting the witnesses at a pleasant dinner-seminar arranged by the Woodrow Wilson International Center for Scholars. During the seminar, I proposed that the witnesses address themselves to four fundamental questions:

(1) If there are limits to growth, where are they found?

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[2] Excerpts from the Limits study, commentary, and highlights from related studies in this field are included in the appendix to this hearing volume.

(2) Is there evidence that any limits are being approached, or have been exceeded? If not, how are limits likely to manifest themselves first?

(3) How soon are such limits likely to present major problems requiring direct, responsive action on the part of society?

(4) How will society have to react in order to ease the pressures that such limits will foreseeably create?

On the basis of the testimony received at the May 1 session, the subcommittee intends to hold a further series of hearings on the following dimensions of the growth controversy:

1. Differing concepts of growth limits.
2. International implications.
3. National growth questions.
4. State and local growth problems.
5. Population aspects.
6. Economic scarcity.
7. Resource scarcity.
8. Pollution problems.
9. Land use.
10. The market process and technology as "cures."
11. Reactions of the executive branch.
12. Wrapup—implications for the committee and the Congress.

To provide all committee members with a succinct overview of the initial hearing, I asked the staff to prepare a summary of the six witnesses' testimony. The subcommittee, of course, takes no position on the views and opinions summarized here.

STAFF SUMMARY: HIGHLIGHTS OF TESTIMONY

(N.B. Summaries appear in the order of witness presentations. Responses to Member questions are included. Paraphrases and quotations are freely intermingled).

GOVERNOR RUSSELL W. PETERSON

It is vital in view of the great rate of change today to be more concerned about future growth factors, especially because decisions related to growth made in one field, or in a particular geographic area can have an immediate impact in other fields and other areas. Recently, the State of Delaware was confronted with the decision of either developing Delaware Bay for major industrial and oil enterprises or preserving the bay for recreation and tourism. The State decided on the latter course by enacting coastal zone protection legislation which excluded such industrial construction as coastal refineries and, within the bay, deepwater port facilities.

This had repercussions on national efforts to relieve the shortage of energy in this country; it also served as a model to other localities interested in dealing with problems mainly on local merits.

Congress should take steps to develop a more realistic energy policy. For example, if we could give incentives for buying lightweight automobiles the car would give twice as many miles per gallon and markedly reduce the amount of solid waste to be disposed of.

It is useful to differentiate between three kinds of growth: demographic, material, and social.

Even if we reach and sustain replacement fertility in the United States, our population will stabilize over the next 70 years, with 40 to 60 million more people than today.

In this country it appears that we have already reached a population size beyond which there are no benefits. Additional U.S. population also aggravates world resources and environmental problems because of higher material consumption per capita in this country.

As U.S. supply requirements for natural resources tend to shift abroad, we lose control over important components of our economy. Increasingly, therefore, it becomes both physically and politically impossible to continue to grow.

There are two aspects to the material growth problem: the first involves increased pressure on the finite environment to provide essential raw materials. The second is the stress placed on our social and political institutions by the rapid rate of change in resource demand. Over the next 10 to 15 years we must produce and install and bring into full operation as much power production capability as has been accumulated up to this point in our history. The limits to growth are barely foreseen in this context of the limited ability of our current social and political institutions to perceive and manage critical economic problems.

Energy consumption in this country is roughly twice the level in Europe. It is difficult for anyone to point to ways in which our quality of life in its intrinsic nature is twice that of the people of Europe. Obviously there is a great deal of room to increase the efficiency in energy use.

Through our increasing demand for energy, we provide Middle Eastern countries with tools that can be used directly to counter our own domestic and international objectives. We see ourselves moving to a period, if we continue this growth, of becoming strategically very dependent on those countries who have, for the first time, power to interrupt critical inputs to our economy.

Those who have a vested interest in growth contend that the American public could never accommodate the changes necessary in order to reduce energy consumption, improve transportation, and so on. The real source of inflexibility is not in the American consumer, but in the institutions set up to serve his needs. I think the popularity of small cars imported from abroad is direct proof of this.

We are now in a period which could well see a steady erosion of the material and social aspects of life in this country, personal freedom both under law and with respect to discretionary resources and the quality of the environment in which we live. The limits are very much present already. They are causing a deterioration in our life and will almost undoubtedly continue to do so as population increases and as economic activities increase.

We must recognize that we are now in a period when trade-offs are so difficult and changes over time so enormous, that we have to develop new planning institutions to augment our current legislative, legal, and executive institutions. Early stages of public education, data analysis, and data gathering should be done in a way which makes

it highly accessible for those concerned, done in an environment which leaves time for creative thinking. We are sadly deficient in new mechanisms for doing that. There is no institution available to Congress on a full-time basis that can provide these inputs systematically for a broad range of issues.

It is easy enough to identify transportation, the environment, energy, urban land use and many other areas which will continue to generate short-term pressures and crises. An analytical staff funded by Congress on the basis of their long-term utility could enhance Congress' ability to respond to shorter term needs. To anticipate future crises, Congress might consider the establishment of an Institute on Crises to lay the groundwork of institutional and technical analysis for constructive response.

ROBERT A. FROSCH

There is a time scale problem involved in understanding the differing reactions to growth. For example, regional disagreement about the nature of growth problems, was evident at the 1972 U.N. Conference on the Human Environment. Highly industrialized nations were most concerned about the effects of additional growth on their own environment and on the global environment. By contrast the developed nations were concerned more about the serious local environmental problems arising from lack of sufficient industrialization. The United States is in the fortunate position of worrying about 30, 50, or 100 years ahead because it need not be so concerned about 5 years or 10 years.

Industrialized nations are primarily concerned about the great human pressure on the global environment, on climate and the state of the oceans. Developing nations perceived the primary problems in terms of local agronomy, the spread of regional deserts, et cetra.

While there may be an overall aggregate limit to growth, within that overall limit there remain many questions of rearranging growth capacities. A particular interest of the U.N. environment program is the question of what growth we may continue to have before reaching severe difficulties.

The problem of interconnectedness of environmental approaches is evidenced when the United States sets particular requirements on pollutants or imports.

While growth problems are most often defined in terms of physical and biological limits, there is a good deal of evidence that these problems may be exaggerated by social limits—the bureaucratic ability to coordinate larger and larger entities and the human difficulties arising in highly concentrated human populations.

There are clear indicators of certain kinds of limits to growth in particular areas of U.S. cities; there are other parts of the country where local people would feel that they have not yet reached their limits.

Congress may not benefit from an analytical group which deals with growth questions, unless the political decisionmakers are somehow involved with the analysts in defining the specific problems and alternatives.

As worldwide affluence spreads, it expresses itself in the rising demand for protein. The situation of rising U.S. food prices confronted in recent months illustrates this phenomenon. The average American consumer has increased beef consumption from 55 pounds in 1940 to 117 pounds in 1972.

Rising affluence also is a major new additional claimant on world food resources. The entire northern tier of industrialized countries stretching from Ireland and Britain in the West, including Scandinavia, Western Europe, Eastern Europe, Soviet Union, and Japan are evolving dietary patterns more or less where the United States was in 1940. A substantial share of the increase in income and purchasing power within these countries now translates into additional planning money for livestock products. Most of these countries cannot meet this additional demand from local resources. We are seeing a very bullish demand for worldwide agriculture products.

The world food market may be in the process of being transformed from a buyer's market to a seller's market just as the world energy market has been transformed over the past 2 or 3 years. The days of cheap food and cheap protein may well be behind us.

A shortage of resources, particularly water, is beginning to constrain efforts to expand food production. Water rather than land is the principal constraining factor on world food production.

As the demand for animal protein rises we are running into constraints in our efforts to expand the three important sources of high quality protein. In 1969 the world fish catch trended downward for the first time in nearly two decades; most marine biologists feel that the world catch is very close to the maximum sustainable level. There are sticky international political issues involved in allocating the catch to various countries once the limit to catch is established in a given fishery.

Major grazing areas for beef cattle are already close to their maximum carrying capacity, dictated primarily by rainfall.

Yields of soybeans have been restrained because soybeans are legumes and have their own built-in nitrogen supply. Soybeans are not responsive to nitrogen as is corn.

Three policy issues derive from the growing world scarity of food:

(1) As consumers of fish we have a tremendous stake in a successful Law of the Sea Conference which begins this year in Chile. If we fail to evoke a cooperative global approach to managing oceanic fisheries, we face a decline in fish and rising seafood prices.

(2) We are now in a situation where it is in the interest of American consumers as well as consumers in the Soviet Union, Japan, Europe, and so forth, to have a global food reserve that would serve as a cushion on world commodity and food prices.

(3) As we begin to experience increasing scarcity at the global level not only for energy but food, forest products, minerals, fresh water, marine protein, and so forth, we need to reassess population projections at the global level.

The technologies that underlie our economic system evolved in a situation of relative resource abundance. As we move into a period of resource scarcity, we need to reexamine those technologies as a means

of reducing energy consumption, foreign exchange problems, and pollution problems.

As we prepare for the U.N. Population Conference in 1974, one of the most important things that could happen would be for the United States to officially adopt zero population growth as a national objective. We are already heading toward this objective.

ALFRED HELLER

An organization has been established to develop a model plan for the future of California, called the California Tomorrow Plan.

The study on which the plan is based indicated clear need for policies and actions in four broad areas:

(1) Establish State planning and budgeting in a central agency for bringing about strong State and regional planning.

(2) Coordination of Federal grants and loans to serve and encourage strong State planning/budgetary operations.

(3) Development of a policy to guide future settlement of population and establish high amenity standards for air quality, pesticide use, transportation, open space planning, and so forth.

(4) Acceptance of a State population policy of zero growth.

STEVEN SALYER

The Commission on Population Growth and the American Future, after spending 2 years analyzing the implications of growth, concluded that the stabilization of our numbers would produce important benefits.

The Commission's research showed that economic growth is not dependent on an ever-growing population.

The research program also found that water shortages, already developing in the Southwest, would eventually spread eastward and northward, despite large projected expenditures on dams and reservoirs. The rate of national population growth will largely determine how soon we must deal with scarce resources.

In addressing the means of stabilizing population growth the Commission concluded that the guiding principle should be to encourage couples to have only those children that are wanted.

One of the most effective ways to reduce the number of children couples have is to increase their opportunities to enjoy other responsibilities and satisfaction, previously denied. Programs enabling women to work, improved day care facilities, increased investments in education, job development for the poor, and family planning information to all citizens desiring it are examples.

As we talk about planning authority we should also be dealing with how to increase the time horizons of individual citizens, and how to translate long-term concerns into individual terms. Education of individuals in order to increase their perception will enhance the Government's ability to plan for these problems.

Barring human catastrophe, we still have opportunity to address the real problems—energy shortages, protein deficiencies, etc.—associated with growth.

The United States must be the first to move in confronting the growth issue; comparatively we have the greatest capacity and resources to assess the problem. Not only does this country have the dollar capital and personnel necessary to deal with these concerns, but if we do not act, it will be difficult for us to bargain in good faith with other nations of the world.

To broaden public perception and reduce our response time special emphasis should be given to public education on these problems. Congressional hearings will stimulate national discussion and hopefully accelerate the decisionmaking process in this important area.

Actual detailed planning should be handled on a local, suboriented or geographically oriented basis, with a top group coordinating and providing parameters for this planning. I believe that the Congress, which in toto has a greater longevity and better time perspective than the Executive branch, should manage this coordination function.

It is difficult to predict the particular crisis that would force the attention of our society to the growth problem. In the field of health, we face some major problems that could again have a huge impact on the world over the next 5 years. World food problems are another potential area.

One of the major problems of understanding growth problems is the absence of an adequate welfare accounting system in this country. No one at this point is making the effort to present the true choices and alternatives in a futuristic sense to the public.

GROWTH AND ITS IMPLICATIONS FOR THE FUTURE

TUESDAY, MAY 1, 1973

House of Representatives,
Subcommittee on Fisheries and Wildlife
Conservation and the Environment
of the Committee on Merchant Marine and Fisheries
Washington, D.C.

The subcommittee met at 10:10 a.m. in room 1334, Longworth House Office Building, Hon. John D. Dingell (chairman) presiding.

Mr. Dingell. The subcommittee will come to order.

Today the subcommittee commences hearings on what may prove to be one of the most important issues of our time: growth and its implications for the future. While in a sense this question has been considered and dealt with by all men in the past, it is presented today with an urgency which is perhaps unique to our time.

No natural system can grow exponentially and infinitely. That is a truth which I think we can reasonably hold to be self-evident. There are, therefore, somewhere limits to growth. Where these limits are to be found, and the costs of exceeding them are matters which must be explored.

The hearings today may serve to start the process of exploration. To help us, we have assembled a truly distinguished group of witnesses, all of whom have outstanding qualifications in their fields. Last night the Woodrow Wilson International Center for Scholars invited these gentlemen and several of us here to discuss these questions in a preliminary way, and those discussions were most enlightening. In the course of the meeting, I presented a brief paper on the purpose of these hearings, and rather than repeat my remarks, I will simply ask that they be included in the record.

[The remarks of Mr. Dingell follow:]

Remarks of Hon. John D. Dingell, Chairman, House Subcommittee on Fisheries and Wildlife Conservation and the Environment

"Growth" and the implications of growth are issues which involve considerable controversy. Some tell us that nothing will suffice, if we are to have a livable tomorrow, but an immediate and total restructuring of society, and our value systems. Others say that this is preposterous—that existing mechanisms of adjustment are and will be adequate to help us ease over the transition period as we progress into a future whose dimensions are slowly becoming clearer.

In my view, this is the critical area of difference between the so-called "prophets of doom" and their critics. None deny that the winds of change are blowing or that the implications of those changes will be substantial. The real decision that we face is between attempting to impose a rational and conscious choice upon the alternatives which confront us, or letting the future take care of itself. And it is important to recognize that the act of making no choice is itself an act of choice.

To choose between alternative futures, we must know something of the nature of the choices that must be made. To do this we must pose questions that have not yet been asked of any society, with the knowledge that we may be playing for bigger stakes than we have ever had to do.

For many, perhaps most, the concept of growth has traditionally been an unquestioned—perhaps unquestionable—good. The first serious questions of this concept have tended to come from biologists and physicists, to whom the consequences of uncontrolled growth have been visible and probable. The softer sciences, such as sociology and economics, have been somewhat slower to get the message—and until the past few years, there has been little effort to explore the implications of uncontrolled growth, or the nature of the controls that might be appropriate.

The questions that we must ask ourselves are not clear. Nor are the consequences of our failure to ask these questions. Neither do we have a good understanding of the time frame within which we must act, if we are not to be foreclosed from exercising rational choices by the passage of time. It is to these issues that the hearings of our subcommittee which begin tomorrow must address themselves. I would hope that the outcome of these hearings will be, at the very least, a focused and thoughtful discussion of these questions, with perhaps some consensus on some of the underlying problems which exist.

I would suggest one such area of possible consensus: I have never heard anyone suggest that there are not in fact some kinds of limits to growth. These limits may be physical, or biological, or social, or economic. I suspect that there are limits in each of these categories, and there may be limits in other categories as well. I would put it to you that we have very little in the way of hard knowledge of what these limits may be. This in turn suggests other questions:

If there are limits to growth, where are they found?

Are such limits already manifesting themselves, and if not, how are they likely to do so?

How soon are such limits likely to present major problems, requiring direct action on the part of society?

What will we have to do to ease the pressures that such limits must inevitably create?

It is human nature, and a significant ingredient in the legislative process, to defer decisions as long as possible. In consequence, unfortunately, we often wait too late to make decisions, and the price of having to play catchup is always high.

When we combine this factor with those relating to the questions of growth policy, the problem becomes acute. The nature of the consequences of growth appears to be such that massive and revolutionary responses may be called for on the part of society within a very short period of time. In fact, it is possible and I suspect very likely, that we are already—consciously or otherwise—making decisions whose long-term consequences are undesirable and may indeed be irreversible.

Some suggest the most dismal theorem of all: that because man tends to react only to crises, the last and best hope of humanity will be in a recurrent series of natural disasters—disasters which will demonstrate to the satisfaction of even the most optimistic or hardheaded that we must change our ways and our values if we are to survive. There is, of course, a substantial risk that such disasters might escalate into worldwide conflict, inducing a cascade of nuclear or other retaliation. If this were to happen, the only survivor may be the cockroach, which has certainly demonstrated a tenacious capacity for survival.

I have to believe that we can do better, (and I do not mean to suggest that this scenario is the most likely available). What I do suggest is that we must greatly improve our capacity for extrapolating the present into the future.

As a first and necessary step, I suppose, we must develop a clearer understanding of where we are now. That is easy to say, of course, and not easy to do. But it seems critical.

Having done that, we may then be in a position to say that in 10, or 50, or 100 years, we are likely to be in such-and-such a position. If that is where we want to be, all well and good, but I have to tell you that I don't believe for a minute that where we will be in 100, 50, or even 10 years if we take no action, is where we would be if we could avoid it. And—and here we get to the nub of the problem, and the reason that we have asked you to be with us at this time—we can avoid these futures if we ask the right questions and do the right things in time. But we have not yet developed the tools or the capacity—and it is far from clear to me that we have developed the will to do what must be done, or to make the sacrifices that will have to be made.

The burden that I am placing upon you is overwhelming. No single person, or group of persons, can carry it. But society must, if it is to survive, and in order to do so, it will require a clear indication of directions, and of the costs and the benefits associated with its actions, (or its failure to act).

I have asked you to be with us today and tomorrow because I am an optimist, notwithstanding the heavy dose of gloom to which you have just been treated. I do believe that it is possible for society to begin to turn itself and to act today for a tolerable tomorrow.

The reason for our inviting you to these hearings is to help us begin the educational process in which the Congress, and the public, should now be participating. No one supposes for a minute that 1 day of hearings can do more than scratch the surface, but it can perhaps describe the surface to be scratched and ultimately penetrated. And if we can do that, I think that we can assume that it will have been an effort well worth while.

Mr. DINGELL. We have circulated to the panel a list of issues that we hope to have discussed today. There may be others that are considered appropriate, and I certainly do not mean or intend to foreclose those. But I think we should consider:

What are the limits to growth?

If so, where are they found?

Is there evidence that any such limits are being approached, or have even been exceeded? If not, how are such limits likely to manifest themselves first?

How soon are such limits likely to present major problems of a kind that will require direct responsive action on the part of society?

How will society have to react in order to ease the pressures that such limits will foreseeably create?

The procedure for today will vary somewhat from our usual hearings: We have asked the witnesses to act as a panel and to feel perfectly free to question each other on points that may arise in the course of today's discusions. Each of the witnesses will give a very brief talk for 5 or 10 minutes on the issues in question, and then the panel will be available for questions from members of the subcommittee. Also, if members of the audience wish to submit questions for possible consideration by the panel, I would invite them to write any such questions down and give them to the clerk, who will pass them on to us.

The Chair is particularly pleased to welcome to the panel the very distinguished Gov. Russell W. Peterson, presently serving on the Committee on the Third Century; Dr. Dennis L. Meadows, Thayer School of Engineering, Dartmouth College who had a great deal to do with the very fine publication *Limits of Growth;* Dr. Robert A. Frosch, assistant executive director, United Nations Environment Programme; Dr. Lester R. Brown, senior fellow, Overseas Development Council; Mr. Alfred Heller, president, California Tomorrow; Mr. Steven Salyer, Citizens' Committee on Population and the American Future; and Mr. Peter S. Hunt, of Peter Hunt Associates.

Gentlemen, if you would please for the purposes of the record identify yourselves so our reporter might keep the names straight. We will recognize you in turn.

The Chair might recognize the particular privilege here we have of being honored by the presence of Governor Peterson. Your energy and knowledge and dedication to the public interest are well known to the citizenry at large and are a matter of great respect by the present occupant of the chair.

STATEMENT OF HON. RUSSELL W. PETERSON, FORMER GOVERNOR OF THE STATE OF DELAWARE

Governor PETERSON. Thank you, Mr. Chairman and members of the panel.

First, I want to commend you, Mr. Chairman and your committee, for sponsoring these hearings. It is vital to Congress and to all the people of our country to pay a lot more attention to the future and to growth.

Failure to make a long-range decision today is much more important to us than it was 50 years ago when the rate of change was much less.

Furthermore, it is increasingly important that in making decisions about growth, we carefully weigh the implications of those decisions because with today's rapid communications the decisions we make here at home can have an immediate impact worldwide. And the decisions made other places in the world can have an immediate impact on what we are doing here in the United States.

It is also clearer and clearer that decisions made in one field can have an impact in other fields without our recognizing it. So to weigh the interactions of our decisions is increasingly important.

There are a number of views of growth or limits to growth. No one of us knows for sure what is the right one, but it is important to get rid of the myths that have been plaguing us, to look for the right knowledge as we steer the way into the future. We must determine where we are today and the directions in which we are heading, and then set goals toward which we wish to move.

One of our first requirements is to become more expert in using the tremendous amount of knowledge that is available in the world so that we can define the trends into the future; and from them the emerging problems. Then we are ready to consider alternative choices for the future, to weigh the desirability of various alternates.

I have been doing a lot of reading lately about limits to growth, arguments pro and con. It pleases me that all of these authors can see an optimistic picture for the future, albeit different kinds of futures. If we make the right decisions today each of them can see a desirable future, one that looks appealing to me anyway.

I think we should look at the grant problem optimistically, recognizing we need to become more knowledgeable of the present and must plan with a long-range view a global perspective and an understanding that decisions made in one field can have a surprising impact in other fields.

Thank you, Mr. Chairman.

Mr. DINGELL. The committee thanks you.

If you wish, you might address yourself at this time or perhaps later to some of the particular decisions with regard to growth that you in Delaware have made compared with the future, some that I think marks great courage on your part.

Maybe you want to save those comments for later, but if you wish to at this time certainly feel free to do so.

Governor PETERSON. All right, I will take advantage of that opportunity.

In our little State of Delware which has only a half million people and only 2,000 square miles we were faced with a decision which had worldwide implications. It is a good example of how a local decision can have tremendous impact on a much broader scale, worldwide, for example.

Sometimes a decision which is right locally may be wrong over a larger region.

Sometimes a decision made on the local basis can set the direction for a worldwide decision.

In Delaware we have an oasis with unspoiled beaches and wetlands used by thousands of people from Washington, Philadelphia, and Baltimore as well as Delaware; a place for fishing and hunting and swimming, for enjoying the outdoors. But that same area became an extremely attractive location for major industrial development. Thirteen of the world's largest oil companies had decided to exploit that area because the Delaware Bay was the best bay on the east coast to receive deep draft tankers. The U.S. Maritime Commission had been working with those oil companies to pave the way for such a venture.

Major transportation companies interested in moving coal from the east coast to Japan and bringing iron ore to the east coast also were interested in exploiting that bay.

We had the opportunity to build as much as $1 billion worth of industrial facilities in 10 years or to hang onto that unspoiled area for recreation tourism. We decided to take the latter course. That led to a knockdown, drag out battle. We eventually get legislation passed which established a coastal zone in Delaware and excluded from that area such industrial construction as refineries and deepwater ports.

This action caused many repercussions. The rapidly increasing demand for energy in this country will probably lead to serious shortages in the near future. To minimize the shortages a tremendous increase in importation of oil is projected. This makes Delaware Bay look more and more attractive to the oil industries as a place to bring in the big tankers.

Let me backtrack a minute. When I was fighting for the coastal zone legislation, I was asked to come here to Washington by the former Secretary of Commerce, Maurice Stans, to explain our position. He accused me of being disloyal to the country. I told him I thought I was being loyal to the country because I was helping to make the decision as to what ought to be the direction our country grows in the future. Delaware's decision might hasten, for example, the movement toward lighter weight cars which will get twice as many miles per gallon of gas, equal to doubling the supply of gasoline.

Mr. Chairman, our decision might also lead to increasing capacity at existing refinery sites rather than building new refineries on virgin land. It could speed up the movement toward conservation of energy and more rapid development of new energy sources. Furthermore, it would make people in other localities have the courage to stand up to build the kind of future that they want in their own area.

This is a classical example, I think, of a local problem being decided on mainly local merits, but having a tremendous impact on the worldwide scene.

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The U.S. Congress, with the responsibility of representing the whole country, should in planning for growth look at the overall impact of land use so that we can keep in proper perspective local zoning decisions and national and worldwide problems and opportunities.

Thank you.

Mr. DINGELL. Thank you, Governor, very much.

Dr. Meadows?

STATEMENT OF DR. DENNIS L. MEADOWS, THAYER SCHOOL OF ENGINEERING, DARTMOUTH COLLEGE

Dr. MEADOWS. Mr. Chairman, I would like to thank you for the invitation to be with you today. I hope in a few minutes to lay the foundations for our conversation today about the long-term costs and benefits in growth.

Population and material growth pose a range of problems that cannot be solved by any one bill, by any single new agency, or by any individual Executive decision. The assumption that growth is desirable and indeed, inevitable, underlies virtually every one of the economic and political institutions in our country. Thus growth is an issue which has its ramifications in each of those institutions.

There has recently been concern over the environmental deterioration and resource scarcity caused by material growth. I am optimistic that if we identify these and other threats as well as the benefits in continued growth we can take appropriate action to realize the maximum benefits and avoid the costs. Until now, the costs of growth have not been identified in advance. Our country has simply blundered into pollution, the energy crisis, and so forth before making any advance preparations to avoid them. The reasons for this lack of foresight will become apparent during the day. This committee will be doing a great service to the other Members of Congress and to the executive branch if it can provide a forum in which it is possible to develop a checklist of the long-term consequences that should be considered whenever a new bill, or agency is proposed.

It will be useful in our conversations to differentiate between three kinds of growth.

First, there is demographic growth involving absolute increases in the number of people in this country. It appears that we have reached replacement fertility in the United States.

If that is true and if it is sustained, then our population will stabilize over the next 70 years leaving us with 250 million to 270 million Americans, 40 million to 60 million more than we have today.

We can take some satisfaction in these trends toward ending population growth, but it should be noted that we have already passed the level of population that would be optimum for our country.

The recently completed Commission on Population and the American Future concluded that there are no benefits to our citizenry in having a greater population.

Of course the people added to the U.S. population each year still have a greater impact on the world's resource requirements and on the global environment than the population added in many of those countries where we think population is "exploding," like India for example. Each American consumes 20 to 50 times more energy, materials, and food (in gram equivalents), than each Indian.

Although the absolute rate of population increase is declining in the United States, we should think about population growth and its implications.

The second kind of growth is material growth, involving increases in the extraction of raw materials from the earth, in their transportation, processing, and use in service, industrial, and consumer products. The deterioration of the environment that concerns this country today can be traced directly to the growth in material usage.

It seems rather clear that there are limits to material growth. The United States, with one-sixth of the world's population currently consumes about 30 percent of the natural resources. It will probably be physically and politically impossible to sustain that high demand on the total resource base. As our sources of supplies shift increasingly abroad, and as we therefore lose control over certain important components to our economy, we will come to understand the very real limits to growth in material consumption and the need, in fact, the inevitability of stabilizing material use so that it is consistent with the physical and the political limits that exist.

The third area of growth is growth in social services: in health, education, culture, and in our understanding of the world and of ourselves. Here it is difficult to see any necessary limits to growth. Indeed, I hope that our economy will continue to expand in its provision of services for some time.

In fact growth in services is more likely if we can stabilize our population and bring material growth to an end.

Associated with material growth are two different kinds of problems. The first is the pressure exerted on the finite natural environment by the sheer physical magnitude of our demands in energy, materials, and so forth. The energy crisis, the high price of food, and environmental deterioration are all symptoms of this problem.

In this problem area, the committee's work is complemented by the work of many other agencies which are addressing the individual symptoms of a strained bio and geosystem. The second problem area associated with growth arises from the tremendous rate of change which material growth imposes on our social and political institutions.

Mr. Chairman, when we realize that over the next 15 years we must mobilize as many raw materials as have been extracted during all of man's history on this globe, over the next 10 or 15 years we must design, manufacture, install, and bring into full operation as much power production equipment as has been accumulated up to this point in our history, we begin to have some feeling for the rapid rate of change which has to be accommodated by a social system experiencing material growth.

Here it seems to me is the greatest area of ignorance. The social and political limits to growth associated with our poor ability to perceive distant problems, and with the slow response times that we have in determining new goals and finding new solutions are as real as the most tangible physical limits. There may even be limits to the ability of our institutions as they are currently structured to manage large, interdependent, socioeconomic systems.

These social limits to growth pose two challenges. Greater time horizons are now required if we are to accommodate increased population and material consumption. A greater degree of lateral intercon-

nectiveness must be explicitly acknowledged in the design of our goals and our institutions if we are to satisfy our national goals in a period of growth.

Although the decisions we make today in accommodating material growth will have an influence on the population 30 or 50 years from now, we make our decisions on the basis of short-term considerations. Political decisionmakers look only at those costs and benefits which are likely to materialize before the next election. Industrial decisionmakers have a time horizon governed by interest rates, 5 or 10 years at the most.

The short time horizon is perfectly adequate if the results of current decisions can be reversed at any point in the future. But most of our important social decisions are now irreversible. Therefore we have to extend our time perspectives, bringing a longer term planning horizon to bear on current decisions.

The lateral interconnectiveness poses a new problem. When two political entities must coordinate their policies, it is possible to construct a new entity at a higher level. This new entity then dominates the subentities and forces coordination between their policies. This has been the response in this country. We have shifted more and more power to the Federal Government. An alternative means of coordination would be to develop new ethics which spell out the obligation of those two entities to each other over time. Instead of continuing the centralization of power this latter approach could be employed to begin accommodating the pressures which are being felt down at the State and local level.

It is within the general conceptual outline outlined above that I will be discussing with you and the other members of the panel today the long-term causes, the costs and benefits of growth.

Thank you.

Mr. Dingell. The committee thanks you and the committee is keenly aware of your interest and concern in this important area.

Our next witness is Dr. Robert A. Frosch, Assistant Executive Director, United Nations Environment Programme. He is also former Assistant Secretary of the Navy for Research and Development.

Doctor, it is a privilege to have you.

STATEMENT OF DR. ROBERT A. FROSCH, ASSISTANT EXECUTIVE DIRECTOR, U.N. ENVIRONMENT PROGRAM

Mr. Frosch. Thank you, Mr. Chairman. I, too, appreciate the initiative and work of this committee in starting more public discussion on this subject.

I would like to expand somewhat on what Dr. Meadows said, but with a global perspective.

At the Stockholm Conference on the Human Environment, there was a general agreement among governments that there were problems with the environment, broadly defined, but a kind of regional disagreement about the nature of the most acute problems. That is, the countries that were highly industrialized and had reached a very rapid growth phase were most concerned about the effects of growth itself and particularly the effects of growth on their environment and on the global environment.

The countries that had not reached the stage of rapid growth were most concerned about the environmental problems that they saw for themselves, stemming in fact, from their lack of growth and their lack of industrialization.

The program that was laid out on the environment in the Stockholm recommendations contains elements of both kinds of environmental problems.

I must note that some of the countries that were less concerned about global environmental effects, because they were more concerned about their own need for development, have subsequently begun to be concerned about the effects of development, particularly if it is not carefully done and carefully controlled.

This, I think, is a global example of the kind of problem of local choice, and what Dr. Meadows has called lateral interconnectiveness.

It also is an example of a time scale problem. In a certain sense, we might say that the United States is in the fortunate position where it can afford to worry about 30 years, 50 years, and 100 years because it is relieved of the necessity to worry about 5 years and 10 years.

The attitude of some of the developing countries is driven by the fact that they are worried about this year and next year and the next 5 years. They might be said to have a concern as to whether their country will last long enough as an internally viable developing entity to worry about the later effects of growth.

This raises another kind of question: if there is an overall aggregate limit to growth, what does this imply about growth and change in individual regions, whether they be global or within the United States?

One could say there are limits to growth when you are talking about an overall limit, and yet there may be, within that overall limit, many questions of rearranging growth and growth capacity. In some cases, there has been a confusion between change and growth, particularly in cases where growth was seen as the only means to economic continuity and to the continuation of employment for sectors of the population.

It may be that change without absolute growth can also be a means of economic continuation and a kind of economic and cultural growth without leading to an overall material growth.

This raises once again the question of time scale and makes the question of when the growth problems become acute very much more pointed, because it makes the time scale concerns of different localities and different regions different.

Within the differences, however, there has been a large measure of agreement on the fact that there is great human pressure on the global environment, in the ordinary sense of pollutants and their effect on health, and in a long range and larger sense, of the effect of human activities and pollutants on climate itself and on the state of the oceans, both for their own sake and because of their effect on the global climate.

Within the developing countries—while these problems are frequently perceived as secondary to them—there are important problems of local human environment, some of which have global implications. These include the spread of deserts, which can be seen as a problem of local agronomy and local economy in many countries, but, nonetheless, if they continue too far and too long to themselves, have an effect on global climate and an effect upon all of us.

The same is true of use and area of the forests of the world. As Dr. Meadows pointed out, as a major consumer of overseas resources, we must be concerned about the effects of our consumption not only in terms of the material that we require, but the effects on the global environment of our consumption (and of everyone else's consumption) of resources, and the effects of this consumption on the means by which international trade is carried out, since these means affect other countries even through the environmental actions that we take to protect ourselves and the global environment.

When we set requirements on pollutants and food imports or other imports, we are having direct effects on other countries which may, because of the long term interconnectiveness, come back and have effects on ourselves later.

In essence, I am afraid that I am saying that when we look at the problem of interconnectiveness on the global scale with respect to growth, it gets more complicated, even, than looking at the internal interconnectiveness of the United States.

One subject that has come up in our efforts to lay out a program following the Stockholm recommendations has been the question of what I might call world materials flow. This relates to Dr. Meadow's comment about the necessity to extract major quantities of resources if we are to go on even with the rate of growth of population that is now apparently inevitable in the United States.

This raises a number of questions on the management of materials, not only in terms of extraction but in terms of use of materials already used: recycling. Something broader than what is ordinarily meant by recycling may be involved. There is a future possibility of a trade-off between renewable resources and nonrenewable resources. In cases of use of extracted and not replaceable materials, we may need to consider the use of other materials which can be grown or otherwise replaced.

Our particular interest in the U.N. Environment Programme is principally in the area of the effects of growth, various kinds of growth, on the environment, and this appears to be an important parameter in the question of what growth we may continue to have, and what kind of growth we may continue to have before reaching severe difficulties.

It is important, I think, to note that while we have attempted to talk about growth in terms of physical problems, and biological problems that are generated by sheer numbers, there is a good deal of evidence that these problems can be exaggerated by social problems that come with numbers and concentrations and that, in fact, the limits to growth may not be physical; they may be bureaucratic in the sense already referred to, the failure of our ability to coordinate larger and larger entities, and they may be social in the sense of social difficulties that arise in highly concentrated human populations.

All of these interacting problems make it extremely difficult, of course, to make predictions that are accurate and, in a sense, the question may not be so much the matter of predicting accurately, but predicting well enough so that reasonable actions may be chosen, so that we may decide in what directions to go, even though we cannot predict very far ahead.

Thank you.

Mr. DINGELL. Doctor, we thank you for a very helpful presentation.

Our next panel member is Dr. Lester R. Brown, senior fellow, Overseas Development Council. He is also former Administrator of the International Agricultural Development Service of the U.S. Department of Agriculture.

STATEMENT OF DR. LESTER R. BROWN, SENIOR FELLOW, OVERSEAS DEVELOPMENT COUNCIL

Mr. BROWN. Thank you, Mr. Chairman. Let me first express my personal gratitude to Governor Peterson and the work he has done in Delaware. As one who grew up on a farm along the Delaware Bay, I appreciate very much what you did there.

Secondly, I want to commend this committee, as have those who have spoken before me, for taking this initiative to air a set of issues that are as critical as any before our society this day.

We badly need illumination on some of these issues, and I would like to use the few minutes available to me this morning not to deal with the broader issues in which I am interested, but which I think have been covered well by Governor Peterson, Dennis Meadows, and Robert Frosch, who have gone before, but rather to take a specific subsector of the total system, the food system, and elaborate on it a bit. There has been, I think, a great deal of confusion as to what or who has been responsible for the rising food prices that all of us have been confronted with in recent months.

Twice in the past several weeks, once in Hartford, Conn., and again in Los Angeles, I watched interviews on TV with some of the women who had organized the protest of a couple of weeks ago, and noted with considerable interest their response to the questions raised by the TV interviewers, "Who is responsible for the rising food prices that you see in supermarkets? Who is your message for? Who are you trying to reach?

The women had great difficulty answering this question. They didn't think the supermarkets themselves were primarily responsible. They did not want to put all the blame on the farmer, and they did not have a very clear idea as to who the middleman was who got two-thirds of the dollars they spent at supermarket cash registers.

What they had never stopped to ask themselves was: Might I be responsible? As an average American consumer we have increased beef consumption from 55 pounds in 1940 to 117 pounds in 1972, and as an average American parent we have contributed to a 57-percent increase in the U.S. population over that period. The combined effect of this doubling of per capita consumption and increase in population has tripled our national beef consumption and has also made us the world's leading beef importer, richly endowed in agricultural resources though we are.

There has been a tendency in recent weeks to blame this on some of the short-term factors at work in the world food situation; the 4.5-percent decline in the Asian rice crop, the steep shortfall in the Soviet wheat harvest, and the disappearance of the anchovies off the coast of Peru for a period of several months. But we should not lose sight of some rather fundamental longer term forces at work here, forces

which I think are transforming the nature and dimensions of the world food problem.

During the 1960's, those of us who were actively wrestling with the food problem then saw the food problem primarily as a food population problem. At the end of each year we would compare the increases in food production with those of population, and it was a close race.

World population growth continues to be rapid, but in the early 1970's we are witnessing the emergence of rising affluence as a major new claimant on world food resources. This increase in affluence is reflected in the increase in consumption of livestock, particularly beef, which I mentionad earlier, that has occurred in this country over the past generation. Now the entire northern tier of industrial countries, stretching from Ireland and Britain in the west, and including Scandinavia and Western Europe, Eastern Europe, the Soviet Union, and Japan, is experiencing marked changes in dietary patterns. These countries are now more or less where we were in 1940 in the evolution of their dietary patterns.

A substantial share of the increase in income and purchasing power within these countries now translates into additional expenditures for livestock products, and as it does, we find that most of these countries cannot meet this additional demand entirely from local resources. They must either import some of the livestock products as such, or import the feed grains and soybeans to produce them.

On the supply side, we are also seeing some very significant new factors beginning to emerge. In a more general way, resource shortages, particularly of water, are beginning to constrain efforts to expand food production. Indeed, I think we have now reached the point where water rather than land is the principal constraining factor on world food production. Environmental constraints in a very broad way are also begining to operate and to affect efforts to increase production.

But as affluence rises rapidly, it is expressed particularly in the demand for protein, and it is interesting to note that just as the demand for animal protein is rising very rapidly, we are running into constraint in our efforts to expand the supply of three important sources of high-quality protein. The first of these is marine protein, seafood.

From 1950 to 1968, the world fish catch increased to a new record each year, expanding by an average of about 5 percent per year. This greatly increased our per capita supply of seafood during this period, but then in 1969 the world fish catch declined for the first time in nearly two decades, and since then it has been fluctuating rather unpredictably.

Many marine biologists feel that the world catch of table-grade fish is very close to the maximum sustainable level. Indeed, of the 30-odd leading commercial species of fish, a large and growing number are now being overfished; that is, we cannot sustain the catch of several of these species even at the current level.

One of the issues that I think is of increasing interest as we look at scarce and in some cases finite resources is how this affects competition among countries for these resources. Once we approach the limits of expansion in the use of a particular resource, we must confront the problems of international competition and allocation—problems much more complex and difficult than merely increasing production of

a resource. The issues shift from how to expand the pie to how to divide the pie. In world fisheries we are now at the point where the issue is becoming how to divide the pie.

The question is, how do you, once you have established the limit on a given species in a given fishery, allocate that catch among countries? Do you base the formula for allocating catch on historical shares, on the extent of investment in fishing fleets, on the size of the population of the various countries involved, on nutritional needs, on coastal proximity, or on any of many other factors?

These are the very sticky international political issues that must be sorted out at the Law of the Sea Conference that begins this year and continues into 1974.

So much for marine protein.

A second area in which we are having difficulty in expanding protein supplies is beef. We have not been able to devise any commercially satisfactory way of getting more than one calf, per cow per year, and so for every animal that we put into the production process, we must maintain one adult animal for 1 year. If it were not for the fact that many of the world's major grazing areas—the Great Plains of the United States, the East African Plateau, and large areas of Australia—were not already close to their maximum carrying capacity, this would not be a serious problem, but unfortunately that is not the case. We are faced with a growing appetite for beef throughout the world, and we are having difficulty expanding supply as rapidly as demand.

A third source of protein, one which is becoming increasingly important, at the global level and for which we are having difficulty expanding the supply, is soybeans.

We have not been able to achieve a breakthrough in soybean yields. From 1950 to 1972 in this country, which now produces three-fourths of the world's soybean product, we have increased soybean yields per acre just over 1 percent per year. That contrasts with 4 percent for corn.

One reason we have not been able to get a breakthrough in the soybean yield per acre is that soybeans are legumes, with their own built-in nitrogen supply, and are not as responsive to the application of nitrogen fertilizer as is corn.

We have increased our production of soybeans fourfold since 1950 but the great bulk has come from expanding the area in soybeans. We get more soybeans by planting more soybeans and according to the planting intentions report issued by the Department of Agriculture in March of this year, more than 1 acre in every 7 acres of cropland will be devoted to production of soybeans in the United States in 1973.

The production of soybeans has increased dramatically in the United States. Our exports have increased even more dramatically. Soybeans have now become our leading export commodity in response to growing world demand for high-quality protein, and we are exporting in value terms more soybeans than we are wheat, or other feed grains. In fact, in value terms, soybean exports exceed those of our high technology exports such as jet aircraft, computers, et cetera.

My basic conclusion from a fresh examination of the world protein situation, one which will update the examination of the food situation I did in "World Without Borders," published several months ago,

is that the world food market may be in the process of being transformed from a buyer's market to a seller's market, much as the world-energy market has been transformed over the past 2 or 3 years. The days of cheap food and cheap protein may well be behind us.

Now, as a country, if there was any area in which we thought we were invulnerable it was in our capacity to supply an adequate supply of low-cost food. But suddenly we find ourselves in a position where we are sharing food scarcity with consumers in the Soviet Union.

Many have asked, including some Members of Congress, why don't we limit our exports of farm products in order to bring food prices down here? If we were to limit our exports of farm products we would bring food prices down to a much more tolerable level, but we cannot forget our growing dependence on imports of energy and other needed raw materials. One way we can hope to pay the growing import bill for these items is to expand our exports of farm products. We really have no choice but to share food scarcity with other countries of the world.

Let me quickly focus on three policy issues that derive from the growing world scarcity of food which loom very large for us as a country. As you know, the Law of the Sea Conference begins late this year in Santiago, Chile. As consumers of fish we have an enormous stake in a successful Law of the Sea Conference, one which evolves the institutional framework whereby we can cooperatively manage oceanic fisheries.

If we fail in this, and it is a very complex, very difficult issue that we are dealing with, then we face the prospect that the global catch of many important species of fish will begin to decline in a rapid fashion, much as they did for whales beginning 15 or 20 years ago when we were not able to achieve the global cooperation needed.

If we fail to evolve a cooperative global approach to managing oceanic fisheries we face both a decline in the catch of many important types of fish, and rising seafood prices which will make those of the past 2 years seem very modest by comparison.

We also need to remind ourselves that we now import two-thirds of all the fish we consume. We are heavily dependent on the rest of the world for our supplies of marine protein.

A second point. If my assessment of the world food situation in the 1970's is correct we are moving into a situation where not only will world grain reserves more likely be low than high, not like the surpluses we had in the 1950's and 1960's, but also where the 50 million idle acres out of 350 million acres of U.S. cropland that we have had over the past dozen years may well be called back into production. Indeed, a major share of it is being called into production this year.

If we find ourselves in the 1970's with low food reserves, and without this 50 million-acre cushion that we have had for the past dozen years, then we need to give serious thought to creating an internationally managed global food reserve, because if we do not we will find ourselves subject to a period of food price volatility unlike any we have seen in recent times.

I think this is an issue that the United States has not as a Government addressed itself to. We are now in a situation where it is in the interest of American consumers as well as consumers in the Soviet Union, the developing countries, Japan and Europe, to have a global

food reserve that would serve as a cushion to help stabilize world commodity and food prices.

The third policy issue which looms large at the global level is population policy.

If we are beginning to experience increasing scarcity at the global level not only for energy, but for food, forest products, minerals, fresh water, marine protein, et cetera, then the need to reassess the implications of population projections at the global level will become a matter of great concern.

We must begin to ask ourselves, if with 3.7 billion people in the world we are experiencing scarcity to the degree we are now, what will it be like at the end of the century with 6.5 billion people?

As we do that, I think the urgency of stabilizing world population growth sooner rather than later will become obvious.

It distresses me that, as a country, we have not established as a national objective, population stability: zero population growth. This is important.

Mr. Chairman, it is particularly important in the international arena, with World Population Year coming up next year. We are being accused of not practicing what we preach because we are pressing other countries, particularly developing countries, to stabilize their populations without ourselves having the stabilization of our own population as an official objective. This is something we could do that could make a great deal of difference at the global level in the way in which people think about the population problem, and it has the great advantage that it does not cost any money, because we are already moving toward population stability.

Not only have we reached replacement, but the birth rate figures for January 1973 indicate a continuing precipitous decline in the U.S. birth rate.

If this trend of the past 18 months continues we will reach population stability, zero population growth, before the end of this decade. No one knows whether that trend will continue, but since we are moving in this direction we ought to take political credit for it in the international arena.

Such a declaration makes a great deal of sense to me and does not require the appropriation of any additional funds.

Thank you.

Mr. Dingell. A most impressive statement, Doctor.

Our next witness is Mr. Alfred Heller, president, California Tomorrow.

Mr. Heller, we are certainly pleased to hear from you at this time.

Mr. Heller. Thank you, Mr. Chairman.

STATEMENT OF ALFRED HELLER, PRESIDENT, CALIFORNIA TOMORROW

Mr. Heller. Thank you, Mr. Chairman.

I want to express my appreciation for being included in this distinguished panel in this important discussion with the committee.

I note we are down to the "Mr." end of the table, having heard from a Governor and three doctors. We have been dealing also in very large-scale concepts and discussing national and international institutions.

The area of my particular interest is the institutional implications at the State level, of the need to take into account simultaneously the many forces that affect the future, including patterns of economic growth and development.

This interest was the basis of an effort of our organization to create a model plan for the future of the State of California, which I will hold up just to indicate we did produce something. It is called the *California Tomorrow Plan.*

Our effort was to determine what are the basic policies and the political and economic structures necessary not only to determine available alternative courses of action for the State, but to bring about those which are duly chosen. I will not dwell on the national implications of this but I think that they are fairly obvious: if this approach has some validity it should be of interest to other States and the National Government as well.

We attempted to derive in a systematic manner basic goals for the State of California, based on an analysis of an array of disruptions—economic and social as well as environmental—which beset the State.

We determined underlying causes of these disruptions, and defined central policies which could be addressed to them.

We concluded, in general, that there is a clear need for policies and actions in four broad areas and for coordination among these basic areas.

First and foremost, we are going to have to develop a set of political institutions by which we can solve our major problems.

We felt that such a system for solving problems within the State of California would have to begin with a single, strong State planning/budgeting entity. We recommended that a State planning council be created, chaired by the Governor and composed of members of the Governor's cabinet and public appointees. The council would have a broad responsibility for developing State policies which address the kinds of issues that Dr. Meadows in the "Limits to Growth" has so effectively brought to the Nation's attention.

We felt that furthermore there was a need within the area of political institutions for comprehensive regional plans and budgets prepared and backed up by regional governments.

The second broad area of policy revolves around the need to maintain a strong economy—that is, to do what is necessary on behalf of the economic strength of individuals and of society as a whole. Individual economic strength, we felt, could best be insured through such means as the provision by the Federal Government of an income floor and of a system of national health insurance.

We felt the need for the State to take a stronger role of leadership to encourage economic development where it is needed and in the manner that it is needed. There are limits, certainly, to certain kinds of growth as Dr. Meadows pointed out but in other areas there may not be as clear limits.

Still in the area of economic policy we determined that the ability of society to finance its conservation and development goals should be analyzed and improved. Within the State we felt a system of planning, budgeting, and financing at the regional level, tied to the regional governmental entity I mentioned earlier, would be an essential for enabling the communities within our regions to begin to meet their needs cooperatively and equitably.

Whether their sources of financing are categorical grants, revenue sharing or other sources, we recommended a supplemental source, a Federal conservation and development bank.

We felt that all Federal assistance to the State should be predicated on the existence of administrative and budgeting institutions which do not now exist at the regional level, but which, as I have indicated, should be developed.

Someone described revenue sharing at the present time as "snow on a hot stove" and I suppose that no matter what happens in the Federal financing area, this same effect will continue until we develop means of actually planning, budgeting, and financing realistically within our regions to make the most effective use of the funds that are available.

Third, we felt the need for strong settlement policy, a policy to guide settlement in California to eliminate damaging distribution of population.

Among the provisions that we felt would be effective in that area would be State zoning of all lands, similar to what is in effect in the State of Hawaii, which would clearly indicate where you can build, and where you cannot build.

Our task force determined that firm State guidelines for the development of the so-called infrastructure, the public utilities arterials involving water, wastes, energy, and information, should be established.

As a further guide to settlement, the State should adopt high amenity standards having to do not only with air quality, water quality, and the use of poisons on the land, but also with other factors such as the availability of transportation, the amount and proximity of open space available to all citizens and many others.

We advocated also, in this policy group, a State population policy of zero growth.

Fourth, we described the need for a series of resource use policies which would include a set of regulations and incentives to guide resource use and encourage recycling.

The point of all this is that none of these ideas is new itself, but, if we can develop a planning process so that all of them can be fitted together and carried out simultaneously, here is what happens, as an example.

State zoning and related tax assessment policies can define broad land-use categories and make them stick. Adopted State amenity standards can establish clear rules for the maintenance of environmental quality.

Basic resource use policies can tell us how far we can go in using our natural resources without ending their availability. Strong State economic development policies closely coordinated with other planning policies can help promote economic development where it belongs and where it is needed.

A rational system of planning, budgeting, and financing with our metropolitan regions guided by a State planning council can fit the pieces together and make the term "urban renewal" or "State renewal" or perhaps "national renewal" meaningful in a way that it has never been.

Thank you.

Mr. Dingell. Thank you very much, Mr. Heller. You made a great contribution.

Next is Mr. Steven Salyer, Citizens' Committee on Population and the American Future.

Mr. Salyer, we are pleased to have you with us today.

STATEMENT OF STEVEN SALYER, CITIZENS' COMMITTEE ON POPULATION AND THE AMERICAN FUTURE

Mr. SALYER. I am a substitute today for John D. Rockefeller III who is giving the first lecture in honor of his late brother at the University of Arkansas tomorrow and regrets he is unable to be with you.

The Commission on Population Growth and the American Future was authorized by Congress on March 16, 1970, to assess the implications for America's future of continued population growth. After 2 years of analyzing the implications of growth for our political institutions, our economic system, our environment, for our society as a whole, we concluded that little would be gained from continued population growth. Rather, the stabilization of our numbers would produce important benefits.

This should not imply, however, that we viewed population increase as a root of all our problems. Instead, it was seen as a multiplier or intensifier of other problems we face.

As is so often true of an effort of this magnitude, we only began the process of investigation which must go on if we are to make informed policy judgments. Our research is now being published—seven volumes of it—and serious scholars can read those studies of interest. But the important point for me to mention is that in no case did we find any persuasive reason why population growth should continue beyond that level practically inevitable because of the baby boom. We did find in numerous instances, however, that the solution of other problems would be made more difficult by further growth. Our conclusion was that the Nation should welcome and plan for a stabilized population.

Two examples of major research findings will demonstrate the argument leading to this conclusion. Growth is almost as much a part of the American tradition as apple pie. An extension of our conventional wisdom tells us that for economic growth to continue we must have an ever-growing population. Our research showed very effectively that this simply is not so.

Using estimates based on two-child average and three-child average rates of population growth, and employing several different economic models, we found that the level of GNP would be very similar in the year 2000 no matter which of the two projections we used. In fact, GNP would actually be higher with the two-child rate for about the next 15–20 years. Furthermore, for the next 30 years and beyond, per capita income—which may be the better indicator of economic growth—would increase more rapidly with the two-child "replacement" rate of population growth. Finally, considering the population increase of about 40–60 million that will almost inevitably occur by the year 2000, we could find no industry, including diapers, that would not experience an increase in sales. Some industries, whose sales are particularly sensitive to increases in disposable income—including, unfortunately, some of the high polluting ones like automobiles and motorboats—would experience far greater growth with the two-child

rate and the resulting higher per capita incomes. In short, we would find no convincing economic argument for continuing population growth.

I will draw a second example from our research on "Resources and the Environment," the section on "Water." We found that water shortages, already developing in the southwestern United States, would spread eastward and northward in the next 30–50 years, given growing population and economic activity. "Such deficits," the report states, "will spread faster if population growth follows the three-child projection than if it follows the two-child projection. This will occur despite large expenditures on water treatment, dams and reservoirs during the next 50 years." The Commission concluded its assessment of water supply adequacy saying:

> Sooner or later water must be dealt with as a scarce resource. The sooner this is done, the fewer water crises will emerge in the years ahead. However, doing this will not be easy, technically or politically—most water supplies are run by local governments. The rate of national population growth will largely determine how rapidly we must accomplish these changes. And few will like the austerity created by the need to conserve on something as fundamental as water.

While in no sense did our research point to immediate fiscal or resource crises, in most every situation the pattern of findings was repeated—no substantial gains from continued population growth set against actual benefits from slowing growth or at least more time in which to solve predictable problems.

We should now logically ask, as did the Commission, just how difficult it is to stabilize population growth, and by what means it might be accomplished.

In a national sample of married women in the reproductive age range we found that 44 percent of all births in the period between 1965 and 1970 were reported as "unplanned," while 15 percent were said to be "unwanted." In further research we refined the notion of the "unwanted" child and concluded that it would be decidedly in the interest of the affected child and mother, as well as for society at large, if we could eliminate "unwanted fertility." The goal of insuring that couples have only those children that are "wanted" seems a reasonable direction for public policy to take, and it became a guiding principle of our report. We discovered that if we could accomplish this one goal, we would reinforce the two-child average necessary to eventually stabilize the size of the population.

Next, as has been widely publicized by those talking of a "baby bust," the birth rate has dropped in recent months to the lowest point in our history. While we must exercise caution in analyzing such short-run figures—as many demographers did not in the 1930's when they worried over rapid population decline—it is nevertheless significant that the family size preferences of those young men and women born in the baby boom years are significantly less on the average than were those of their parents. If this trend continues and these preferences are realized, we should continue at close to the two-child replacement average.

Finally, the Commission discovered that generally one of the most effective ways to indirectly reduce the number of children that couples have is to increase their opportunities to enjoy other responsibilities and satisfactions, often previously denied them. This applies with particular strength to women and to the poor. While it is not difficult

to get plenty of argument on this point, it was our conclusion that, in the long run, programs for instance that enabled women to work—like proper day care—would not encourage the birth of additional children.

Moreover, increased investments in education and in job development and training for the poor would likely lead to smaller families by choice. The principle is well illustrated by the observation that the smallest average family size among any group in the United States is among college educated blacks.

The Commission made it very clear in its own statement of priorities, however, that even if the provision of day care or of better job opportunities proved to marginally encourage larger families, these efforts were so fundamentally important as to override the population growth considerations. We tried to say as forcefully as we knew how that this was not a commission concerned only with the numbers of people, but that we cared deeply and primarily that every person have the opportunity to realize his or her full potential and worth as an individual.

At a time when we know so little about the determinants of "growth" in its many forms, when our control mechanisms seem so fragile and perhaps inadequate, it seems all the more urgent that while the interrelationships are clarified and the public alerted we undertake those steps which will gain time for addressing the broad, long-term issues of "growth." The Commission refreshingly demonstrated that in this one part of the "growth" picture—that of population increase—we could solve our problem simply by the adequate provision of family planning information and services to all citizens desiring them. We would be foolish, indeed, not to seize on this hopeful, important, and politically feasible lever on the growth problem.

Thank you very much.

Mr. Dingell. Thank you very much, Mr. Salyer.

Our next witness is an old friend, Peter S. Hunt, president of Peter Hunt Associates. He has testified before this committee on NEPA and is also a member of the President's Advisory Council on Environmental Education.

We are pleased to welcome you back to the committee.

STATEMENT OF PETER S. HUNT, PRESIDENT, PETER HUNT ASSOCIATES

Mr. Hunt. Thank you very much, Mr. Chairman.

First let me say what an honor it is to be here among this distinguished panel; and secondly, I am in substantial agreement with the statements of all the previous witnesses.

I have three points, however, that I would like to make. Some have been made before, but I will make them again for the reason of emphasis.

First, the problems associated with growth, with both population and consumption, not only in this country and throughout the world, are real and deserve urgent attention. Several major reports that have come out in the last year have addressed this subject, and it is unfortunate that they have been belittled unnecessarily by their critics.

We see in the statements by Dr. Brown particularly that we do have indicators today that the importance of these coming problems—energy is one indicator which is expected to rise substantially over the next several years, and, of course, the great problem with beef and protein. The point here is that the problems have been induced and amplified by aspects of growth. Barring a major human catastrophe, which is a very heavy price to pay, they are not going to go away in the future.

Beyond this, I think it is quite clear that unattended they are going to become considerably more severe and have a stronger impact on the consumers of this Nation and, indeed, the people of the world.

With this in mind, I think it is important for us to recognize that the United States must be the first to move in this area of controlling growth. First, from a comparative standpoint, we have the largest resource surplus of any country in the world.

When I speak of resources, I am talking about not only dollar capital but the human talent in this country to assess these problems. Indeed, if we do not move, it going to be very difficult for us to bargain in good faith with the other nations of this world about their growth patterns.

The third point is that we do have institutional problems. The response time in this country of our institutions in this large system to meet and effectively deal wtih problems is tortuously slow.

Problems have to reach crises proportions before they are even addressed.

In line with this, it occurs to me from a system's standpoint, there are three ways we can move. We can look for stronger signals in essence of the problems and read the indicators that we see in energy and food production.

We could, of course, shorten the decision time by having these signals come to the attention of the Congress and the President at an earlier date. And, third, of course, is improving our capacity to deal with these problems once perceived.

Within the United States I think there is one element that must be taken very seriously as far as accelerating the response time to these problems and planning toward the future. That lies in the area of public education.

The members of this panel, I think, would find themselves in agreement on at least 80 percent of the concepts or ideas that have been brought forth here today.

The public, unfortunately, and indeed Members of the Congress, are not as aware of these problems as they should be. If they had the perception of this panel, we would have been moving quite some time ago and in a much more vigorous manner.

As far as these hearings are concerned, I strongly hope that they will accelerate the decisionmaking process on these most vital issues for our country and, by so doing, for the world. Thank you very much.

Mr. Dingell. Thank you, Mr. Hunt.

The Chair will now recognize members of the committee for questions.

The Chair notes that we have large numbers of our committee present today. It may therefore be necessary for the Chair to comply with rules whereby the Chair is directed to recognize each member, in turn, for a period of 5 minutes.

The Chair recognizes Mr. McCloskey first.

Mr. McCloskey. I wonder if anybody on the panel could comment as to whether or not the Congress, unlike the President, should not indicate some acceptance of the recommendations of the President's Commission on Population and National Growth.

This is not a partisan matter, but most of the recent Presidential reports have been immediately rejected by the President than an office.

It seems to me the comments of the panel suggests we should move. Would anyone in particular like to comment on that?

Mr. Salyer. I would like to say a couple of things.

It is exactly right that the President's response was not what we had hoped for. Some in the administration have been more positive in their reactions, however, as you may know.

I think the most informed and productive thing would be for Congress to pick up some of the Commission's recommendations and suggestions.

Mr. McCloskey. As I heard members of the panel discuss this morning, you hit most of them, land use being one.

Mr. Salyer. That is right. And I think there are other key measures.

One is a renewal of title 10 of the Social Security Act, providing family planning services for those who cannot afford them.

Also, the Congress could dramatically increase the amount of research, done in the National Institute of Health on population research. In the United States, many are afraid of the contraceptives they are using. One hundred percent safe and effective methods could eliminate this concern and could enable us to better assist other nations to grapple with their problems of population growth.

In the area of land use, you have several bills before the Congress. They do not represent perfect legislation, and serious attention should be given to how we can successfully encourage comprehensive land use planning on the metropolitan, State, and Federal levels.

I would like to offer one reaction to the idea of a stabilization resolution. Our Commission, while still meeting, endorsed the stabilization resolution that was introduced in the Senate.

As time went on, however, I think our attitude shifted on that matter, at least by the time the Commission had concluded its work.

There was a feeling among the membership that setting a national goal of "population stabilization" through a sense of a Congress resolution was less important than action on the elements of population policy.

Thus, the Commission came to doubt the usefulness of a "population stabilization resolution," especially since it inspired fear and mistrust among elements of our population and because it had no program attached to it.

Mr. McCloskey. Let me ask this question, if I may.

Assuming that growth of population is at least no longer Government policy, is there any sentiment that perhaps we should have a national policy to reduce pressures for the increased consumption of energy, nonrenewable resources?

Would anybody like to comment on that?

Should we now perhaps try to discourage the increase in the use of electric energy, for example, or the increased burning of fossil fuels?

Should this be part of the national energy policy, that we no longer try to increase production, consumption of energy?

Governor PETERSON. Let us talk about oil, for example.

As one of the principal sources of energy with which we are concerned today, it seems to me that the Congress should take some steps to bring a more realistic policy toward the use of the automobile.

For example, if we could make the use of a lightweight automobile attractive by requiring no license fee, as compared to $200 for a heavy car, we might double the average number of miles obtained per gallon of gasoline. That would be equal to doubling the supply of gasoline.

If we go to a lightweight car, this would also markedly reduce the amount of other material resources required by the auto industry, reduce the energy needed to produce such materials, and decrease the solid waste.

It seems to me that the movement in the auto industry toward heavy cars that use up more energy and other resources, cause greater air pollution and go 120 miles an hour when speed limits are all below that, is ridiculous. Some kind of governmental leadership is necessary to make people recognize the tremendous stake in our carrying with us some smaller weight of auto when we go shopping or to work or on a trip. That is one area where I think you Congressmen can have a major impact.

Mr. DINGELL. Mr. Meadows, do you have a comment?

Dr. MEADOWS. Stabilization of our use of materials and energy is not an end in itself. It is desirable only if it serves other goals. Any long-term analysis of the consequences of increasing our demands for energy and materials would suggest that it would satisfy many national interests to stabilize that use as quickly as possible. Looking only at the world's energy demand for a moment, will illustrate this fact. If current growth trends are sustained, we will move quickly into a period where around $20 billion a year must be transferred from our economy to a small number of Middle Eastern countries to purchase oil. Most of those countries have no good use for that money domestically and they have international political objectives very different from our own. By increasing our demand for energy we provide those countries with funds that can be used to directly counter our own domestic and international objectives.

Other examples of benefits derived from limiting growth are easy to perceive. If current growth rates in nuclear energy production are sustained, we will soon be managing a stockpile of nuclear materials so great that it will be virtually impossible to insure that they are not, diverted to uses as poisons or explosives to further the aims of small radical groups.

Thirty of thirty-six raw materials are now imported wholly or in part. If growth continues, we will quickly move into a period of increasing strategic dependence on those countries who have, for the first time, power to interrupt critical inputs into our economy. Finally, we see in the continued growth of the energy many pressures which will force us to relax the environmental standards that our Congress has set, both in terms of water quality and ambient air standards.

This growth is not essential to our quality of life. Our per capita energy consumption in this country today is roughly twice the level in Europe. It is difficult for anyone to point to ways in which our quality of life is intrinsically twice that of the people in Europe. There

obviously is a great deal of room to increase the efficiency in energy use.

If we can become a bit more farsighted about the implications of continued growth, there are reasons enough to begin to stabilize the consumption of materials and energy. There are many ways in which Congress can act now to do that. Governor Peterson has mentioned some policies that might be undertaken with respect to transportation, and there are many others as well. Roughly, 40 percent of our energy is used in space heating, and much of that leaks out through walls which are very poorly insulated. Better standards of building construction would help us a great deal in the conservation of energy.

Current agricultural practices use much energy. Different agricultural methods would save energy. New economic incentives could be provided by Congress in this area.

The goal of stabilizing material and energy use is not an end in itself. But there are many good reasons to look at the components of that use and to move toward ending growth in the various sectors of demand.

Mr. DINGELL. Dr. Brown, you indicated you had a comment.

Mr. MCCLOSKEY. Mr. Chairman, can I interrupt and ask for unaimous consent that we suspend the rules so that all members can interpose questions?

Mr. DINGELL. The Chair will certainly recognize very liberally the rights of members to yield at any time.

Dr. Brown?

Dr. BROWN. In response to Congressman McCloskey's question, I think we have reached the point in this country where we have to begin to seriously examine lifestyles.

We are, as everyone knows, 6 percent of the world's people, somewhat less than that, and we consume one-third of the world's resources. As long as the resources came primarily from within our boundaries, how much we consume, and at what rate, was largely an internal matter.

But as we are now in a period of rapidly growing dependence on resources that are located in other countries, how much we consume and on what terms we consume is something that the rest of the world is going to have something to say about.

I am not at all sure they are going to permit us to continue to pursue super affluence in a world of growing resource scarcity. And if my assumption is correct, then we ought to begin addressing this question as soon as possible so as to reduce the political stresses that will develop at the international level.

Basically, the technologies that underly our economic system are those which have evolved in a situation of relative resource abundance. And we are now moving into a period of resource scarcity for many important resources, protein, petroleum, water, and what have you.

In these circumstances, we need to reexamine those technologies, and I would underline the need that has been mentioned by Governor Peterson and Dr. Meadows, to look at the size of the automobiles.

One can make an argument we would not reduce our individual mobility at all if we limited the size of automobiles. We would certainly not only reduce energy consumption and pressures on the dollar, but also the air pollution problem, and probably would increase our individual mobility somewhat because with smaller automobiles one could park somewhat closer to where you are going.

The second point you raised, Congressman, was regarding a Congressional Resolution on the need to have population stability as a national objective. I approach this from the vantage point of the Overseas Development Council, where we are concerned with global problems and, more specifically, with conditions in the developing countries.

One of the things that is now becoming clear as we prepare for the U.N. Population Year and the Population Conference in 1974, is that a number of the developing countries—and this is where most of the world's people live—are becoming somewhat concerned about the Conference and the focus on population growth. Many of them think of this as a form of imperialism and genocide as long as we, ourselves, do not have population stability as an objective. It is very easy for them to use this argument and with considerable merit.

I think one of the most important things that could happen anywhere between now and the beginning of the Population Conference next year would be for this Government to officially adopt zero population growth as a national objective.

Again, I repeat it is not something that requires an enormous budgetary expenditure because we are headed there already. Let us take credit for it.

Mr. DINGELL. Mr. Breaux?

Mr. BREAUX. Thank you, Mr. Chairman. And I want to thank you gentlemen for your testimony. I look forward to reading your report in more detail.

Governor Peterson, I would like to applaud you and the people of Delaware for the decision concerning the offshore superport. I hope it is the right decision, although only time will tell us that.

As I interpret this decision it was based on a choice either to build a superport or a deepwater port or else preserving the environment for recreational purposes. It has been my feeling that both could coexist, and was wondering if you'd care to elaborate on that premise.

Governor PETERSON. The two could not coexist in the same area. We have a good example right now in our area, the northern part of Delaware and adjoining Pennsylvania, of a tremendous collection of refineries and petrochemical complexes. Even if you assume that they could become 100-percent pollution free, their physical presence still would be incompatible with the way of life which we are now enjoying along the bay and ocean shores in lower Delaware.

Also remember that even though you have a plant operating free of human errors, equipment failure, spills, and so on.

I cannot imagine a collection of tanks and pipelines and distillation columns being planted along the Delaware Bay and the Atlantic Ocean front without running it as an attractive recreational area.

No, a major industrial complex cannot coexist on the same land where you plan to swim, hunt, fish and be able to enjoy the open spaces.

Mr. BREAUX. It seems to me we come to the point in our society where it is a question of balancing the interests and the ultimate needs of society.

Off the coast of Louisiana we have a great deal of exploration and offshore platforms, and rather than having the effect of harming fishing, for example, it has greatly increased the potential to catch

fish, both commercially and for sporting purposes, and has had very little, if any, adverse effects on recreation.

Governor PETERSON. I do not know the basis for your conclusion there.

Mr. BREAUX. The basis is a report of the Louisiana State Wildlife and Fisheries and U.S. Department of Interior.

Dr. Brown, I would like to question you on some of the things you brought out. I thought they were very interesting, particularly the question of the food problem. I would like to direct your attention to the green revolution in areas of Southeast Asia a number of years ago which was supposed to solve the problems of food supply in those countries.

Apparently, it has not.

Has it been successful or a complete failure, or what?

Dr. BROWN. Mr. Breaux, I do not know anyone who thought the green revolution was going to solve the food problem. Some of the more optimistic, and I was among them, hoped it would buy enough time to cope with the population variable, which is the only real solution to the food problem. There is a tendency to denigrate the green revolution as being dead now because, this year, Asia has had a very poor weather situation, unusually poor for the entire continent to be effective.

It is worth noting, however, that given the monsoon failure that India experienced last year, because of the very substantial food reserves they had built up earlier, they probably are only going to import 2 or 3 million tons of grain this year. That contrasts with 10 million tons in a similar situation in 1966.

It is also useful in trying to assess the green revolution to ask ourselves the question what would things have been like had there not been a green revolution? And only when you sketch out that grim scenario, particularly for Asia where more than half the world's people are today, can you appreciate what the green revolution has done.

The green revolution did permit India, in 1972, to reach for 1 year at least, economic self-sufficiency in cereals. That is not nutritional self-sufficiency, but farmers were producing as much as consumers could afford at prevailing prices. That, I thought, was a remarkable accomplishment for India.

I should point out that for wheat, which is where the really spectacular breakthrough has occurred in India, that they have increased the wheat crop from 11 million tons in the mid-1960's to at least 27 million tons this spring. That is a dramatic advance in a major crop, unmatched by any other country in history, including our own.

Mr. BREAUX. Thank you, Mr. Chairman.

Mr. DINGELL. Mr. Steele?

Mr. STEELE. Thank you, Mr. Chairman.

I would like to just ask one question regarding the oil import situation and energy situation.

The Joint Committee on Atomic Energy of the Congress has just finished a new study in which they note that according to the accepted projections, the amount of energy we will consume in the year 2000 is approximately 120 million barrels of oil equivalent per day. In an effort to set some parameters of what we are going to have to do in this country to meet our energy needs, the Committee has arbitrarily

reduced that figure by 27 percent to about 87.5 million barrels of oil equivalent per day as the rock-bottom energy demand level for the year 2000. In doing so, the Committee report notes that 87.5 million barrels could be so low that people might not tolerate it in the year 2000 because of the decrease in our national rate of growth and because of the decrease in our increasing personal consumption of energy that it would entail.

In any case, they have been trying to deal with the question of how much energy the U.S. is going to need by the year 2000.

I wonder if you gentlemen, any of you, have dealt with that particular question and what you feel a feasible target for the year 2000 is that this Nation can live with and which would be politically acceptable.

I will not direct it to anyone in particular but if anyone would like to address that question I would appreciate it.

Dr. MEADOWS.

Mr. Steele, that is an important question; unfortunately it has no simple or precise answer. The answer will depend in part, on the nature of the national energy policy we ultimately implement.

However, we must recognize that the era of cheap power is past. That is desirable, because cheap power has contributed to many of the problems in this country today: inadequate mass transportation systems, deterioration of the environment and so forth. If we selectively raise the price of energy and engage in a vigorous program to develop alternative energy sources and to conserve power, we could easily live within an energy budget substantially below the barrels of oil equivalent that has been projected by the AEC.

I repeat, per capita energy consumption in this country is something like twice that available in Europe. There are enormous savings possible.

We have come finally to the end of the period when the actions of our Government were predicated on the belief that cheap power was an absolute, a sanctified objective of this economy. The transition to an era of realism about energy costs has come very rapidly. Thus I am very optimistic that the changes needed to stabilize our use of energy could also come quickly. Those changes could be accommodated within this country politically within a period of 30 years if we begin now to plan for the long term. Of course any successful plan must focus on consumption as well as production.

I am encouraged by the recent proposal of Senator Jackson to initiate a really vigorous program of research into the energy needs of this country. I was disturbed, however, to see that that focus was almost entirely on expanding production. The proposal completely ignored the vast range of objectives which could be addressed to reduce consumption.

The joint committee's projections are nothing more than a simple extrapolation of past trends. As long as we attempt to meet those projections we will sustain growth in consumption of energy until the costs become unbearably high. The alternative is to look at the consumptive needs of the society and to determine how they can be satisfied in a much more economical way.

Over a period of 30 years this country could come to a period where we were no longer forced to increase our energy demands year after

year. We can do this only if we have the imagination to look out at a distant point of time and if we take some more creative responses to the options that are open to us. Should we instead continue to look only 2 or 3 years ahead and attempt to simply sustain past trends, then unacceptable political consequences are inevitable.

Mr. STEELE. Thank you.

Mr. DINGELL. Dr. Frosch?

Dr. FROSCH. I think there is a tremendous amount of room for more efficient use of energy.

I have been living for the past few months in Switzerland, which can hardly be described as a nonaffluent economy, but I found myself very rapidly getting used to driving a small car at slightly slower speeds and now find myself a little uncomfortable at the size of automobiles that I find myself driving among.

A more interesting shift was that when I came back to the United States I found myself uncomfortably warm in nearly every building I was in because I had simply adjusted to a heating system that runs 5° lower over there. Perhaps I wore a sweater more often.

There are more subtle problems of policy involved in the question of how you get to more economic systems of energy.

My suspicion would be that just raising taxes on gasoline is unlikely to have a very dramatic effect. The policies that seem to have led toward small automobiles in Europe were policies—as Dr. Meadows pointed out—that dealt with the automobile itself, in a tax manner that dealt with size or weight or horsepower in a very strong manner.

The problem of efficiency in space heating and the tremendous loss of energy from the fact that we do not build heavily insulated houses is in itself a rather difficult and subtle problem.

There again, the price of energy is not likely to be the most controlling matter.

Certainly, many of us would be perfectly happy to buy a better constructed and better insulated home, but the personal economic crossover between capital investment in the house and the problems of acquiring mortgages as opposed to the cash flow problem; paying more for energy, are such that fiscal problems push us in the direction of buying a less well-constructed house and paying more for our energy.

While there are great technological opportunities, I think they pose very severe policy problems as to what kind of economic policy and other policies would, in fact, produce the incentive that would drive us toward a more conservative use of energy.

Mr. DINGELL. Mr. Heller?

Mr. HELLER. I just feel moved to comment on this question of Congressman Steele's.

It seems to strike directly at the whole issue of how we plan for our future. No matter what figure you decide on for energy, it would have profound effects on our economic process and on the ways of life that Dr. Brown referred to.

Now, if we are to plan effectively, it means that we are going to have to take into account at the national level as well as the State level, and here I am getting a little bit out of my sphere, but I think that it is right to say we are going to have to operate at the national level in a comprehensive and integrated way.

Our California Tomorrow recommendation for a State planning council chaired by the Governor, responsible for broad statewide environmental, economic, and social policy might well have some application at the national level.

I am aware that Senator Humphrey has proposed a national growth bill which addresses some of these questions, but I am not too acquainted with the details.

Mr. Steele. Thank you, Mr. Chairman.

Mr. Dingell. Mr. Studds?

Mr. Studds. Thank you, Mr. Chairman.

Gentlemen, I do not think I would dare to begin to attempt in 5 minutes or perhaps even 5 hours to address even a segment of what you have been attempting to focus our attention on.

You have dealt with problems, of energy, population, food resources, and, I suppose in a related way, the whole question of the life style of people in this country, ways in which it might have to change whether we like it or not.

For me, one of the real lessons of this morning was mentioned by Mr. Hunt when he referred to the slowness of our institutions, our institutional response. I can remember in days when I was living a more rational life and did such exotic things as read books. I read Dr. Brown's earlier book which led me to do a good deal of thinking. When you are elected to Congress you become an early victim and lose the privilege of reading books and forming thoughts.

In the earlier ringing of those bells, we do not know whether we are going to deal with the closing of a military base when we go to the floor or what and you gentlemen can proceed to go back and think and write some more. In your capacity to read and think and do the kind of research, given the structure of the Congress it is utterly behind the individual Member or the staff of individual Members of Congress that somehow we can bring these two things together.

This dialogue will not be a momentary kind of thing and we will both go our separate and I think dangerous kinds of ways, but I think we can come together again and again in terms of specifics. We need you and people like you very, very much. As I say, I hesitate to ask any particular question.

I wonder if any of the areas of the sea you mentioned Mr. Hunt, that we tend to react only to a crisis. I think that is true. A crisis is a crisis is a crisis which means we are constantly in a state of crisis. Do you see in any of the areas that you are talking about anything that might force even the attention of this finite institution?

Mr. Hunt. This is a major problem. What is going to be the first severe problem to hit us? From the standpoint of predictive models I do not think I could put my finger on any one single issue.

It is a question of probabilities. Each issue from famine to wide spread human mutations has its own probability of occurrence, and hence there is no certainty as to which will arrive first or have the most serious impact.

In the field of human diseases we have seen two new and potentially catastrophic varieties surface in the last 5 years. I refer to the Lhassa and Marburg viruses which fortunately were isolated and brought under control. Had they not, or for that matter should the much rumored man-developed pneumonic rabies escape the laboratories mankind faces a pandemic of unimaginable proportions.

The probabilities of each or any of these problems occurring in the next year, 5 or 10 years are difficult to assess. But they are possibilities and should be recognized as such.

We have similar, although less dramatic, possibilities of crises in the field of world food supplies. I am sorry that Kenneth Watt is not here to explain the impact on food production that a volcanic eruption on the scale of Tambora, which occurred in 1815, would have on the world today. It would most certainly result in hundreds of millions of incremental deaths related directly or indirectly to starvation, and to date we have no way of controlling a natural phenomena such as a volcanic eruption.

The point is that we have a host of potential major problems with differences in both severity and probabilities of occurrence. That there are no easy answers or clearcut priorities in no way diminishes the realities of the situation. I hope that to some degree this answers your question.

Mr. Studds. It was not specifically directed to you. It was an open question. I appreciate it.

Dr. Brown. I think one of the potentially serious short-term problems would be that which would arise if we do not have a successful Law of the Sea Conference coming up late this year, and there is no assurance we will.

There are some very complex and difficult issues to deal with. If we should fail in the fisheries area to get the cooperative global management that is needed, then we will face the possibility in the very near future of a sharply declining catch of some of the important commercial species of fish.

In a world where the current catch is close to 40 pounds per person of live weight seafood this is important and the stress that would develop, in the international economic and political systems as a result of this could be very serious, in part because some countries have come to depend very heavily on oceanic protein supplies. I cite specifically Japan and the Soviet Union. Japan, beginning several decades ago, turned to the oceans and so today the Japanese are now consuming 70 pounds of fish per year and only 7 pounds of beef.

The Soviets, I estimate, are consuming 30 pounds of fish per year, which is nearly triple the U.S. consumption.

If conditions in world fisheries begin to deteriorate rapidly, then those two countries will be very vulnerable and can be expected to react in ways that are at this point very difficult to predict.

Certainly, if things go the wrong way in world fisheries, then we can expect a great deal of pressure on land-based protein supplies that otherwise would not exist.

Mr. Breaux (presiding). Dr. Meadows?

Dr. Meadows. I would like to respond to an implication in an earlier question. It is often suggested by those who have a vested interest in growth that the American public could never accept the changes that would be necessary to stabilize the use of energy or materials. It seems to me the real source of inflexibility is not in the American consumer but in the institutions that are set up to "serve" his needs.

In the transportation industry we have enormously rigid industrial organizations whose leaders proclaim that they must behave the way they do only because the American consumer would not accept another

mode of behavior. The popularity of small cars imported from abroad is a direct counter diction of their claims.

Produceds om nonreturnable bottles claim they cannot recycle their products because the consumer would not accept the inconvenience. Yet returnable containers were the dominant type throughout most of this century. It is the economic institutions, not the consumers, who currently fight the legislation banning nonreturnables. Our citizens are much more flexible than we may perceive.

Congressman Studds has inquired about crises and Mr. Brown has suggested a few possibilities. There are other potentials for crises involving nuclear materials either through accident or through their deliberate use in the hands of terrorists. By its own admission the Atomic Energy Commission does not today have sufficient control over fissionable materials to assure that there are not bomb quantities of plutonium and other materials in the hands of people who might use them for their own use. The situation will become much worse if growth in the use of atomic energy is continued. If current trends were extrapolated then only 1 percent of the nuclear materials stored by the AEC in the year 2000 will be sufficient for 1,000 Hiroshima-type bombs.

There are a number of these crises that we can anticipate. It is not useful to dwell on the idea of catastrophe unless it leads us to some constructive response. One such response would be the creation by Congress of a council or a center or an Institute on Crises. The Center could identify those areas where there is a finite probability of disaster and could lay the groundwork of institutional and technical analysis required before the crisis occurs. Without this preparation we will lack the reasoned background upon which to respond when the crisis is upon us. Metaphorically, we will find ourselves at 3 minutes to midnight pondering desperately to identify what constructive alternatives exist, and with insufficient time to create new solutions. A number of other countries have initiated moves in this area. They have created study groups on conceivable crises. We could easily do the same.

Mr. Breaux. Are there any other comments in response to Mr. Studd's question?

If not, we will now call on Mr. Mills.

Mr. Mills. Thank you, Mr. Chairman.

I have a number of questions. I think this has been a most enlightening proceeding and I for one appreciate the testimony that has been given.

I wonder, considering the fact that it is unlikely we are going to change in the very near future to all small automobiles. I wonder if you might comment about the increase in consumption of gasoline caused by the emission controls that are required.

It would seem we want clean air and at the same time we have a fuel shortage and I am just wondering if there is a thought that you might have since we obviously are not going to change to the small cars all at one time.

Dr. Brown. It might be that we may have to shift to small cars much more rapidly than many of us now anticipate both for reasons of energy conservation and of air pollution.

If one looks at the plans that several cities have been working on, around the country to comply with the Clean Air Act of 1970 by

1975, one has to be impressed by their stringency, by some of the steps that have to be taken to comply. The year 1975 is not very far away and my guess is that the obviousness of the need to shift to smaller automobiles, both at the national level in terms of reducing national dependence on energy supplies and at the individual level, may begin to escalate very rapidly.

I have said before that we have seen some rapid changes in attitudes in this country over the past several years, particularly the past few years, on such fundamental things as childbearing and family size. If we can change our attitudes on the size of the families then perhaps we can do it just as rapidly on the size of automobiles, which is not quite as intimate and so deeply woven into the social fabric.

It may well be that 2 years from now we will react to the idea of driving 4,500-pound automobile that gets 8 miles to the gallon and creates a lot of air pollution in much the same way we now react to a person who announces his or her intention of having 10 children.

Mr. Mills. Thank you. I will forego any further questions. We have 8 minutes to answer a quorum call. That precludes us from doing anything else.

Mr. Breaux. Thank you, Mr. Mills.

I would like to thank at this time the distinguished members of the panel. I think everybody is in agreement it is certainly one of the most prestigious panels ever assembled before this committee.

The congressional research service has prepared a series of documents on background materials for these hearings and without objection we will include them in the record at the close of today's hearings.

[The documents are found at p. 59:]

Mr. Breaux. Without objection, the subcommittee will stand in recess until 2 o'clock this afternoon.

[Whereupon, at 12:20 p.m., the subcommittee recessed to reconvene at 2 p.m., the same day.]

AFTERNOON SESSION

Mr. Dingell (presiding). The subcommittee will come to order.

This is a continuation of the hearings commenced this morning on the subject of growth. The subcommittee is considering the problem of growth and its implications for the future.

The distinguished panel that was with us this morning is in large part here with us this afternoon and, of course, the members are here.

The Chair is particularly pleased to welcome back Governor Peterson, Dr. Meadows, Dr. Frosch, Mr. Heller, Mr. Salyer and Mr. Hunt.

The Chairman will recognize for the purposes of beginning the questions the Counsel of the Subcommittee, Mr. Potter.

Mr. Potter. The questions that were raised and discussed this morning leave a great area for potential discussion and I am a little hesitant of sticking my toe in the water because we did cover so much ground.

It was interesting to me that in the panel of widely different backgrounds and responsibilities, what they were saying seemed to cluster. What they were telling us it seems to me, the message that I got, and I would be interested in knowing from you if I misinterpret it is that in fact there are growth problems and that they are urgent.

The precise nature of the urgency is not clear and perhaps only more information can clear it up. How to get that information is probably going to be the last question that we ask you today.

I take it that it is the consensus of the panel that there are in fact some kinds of limits to growth of different kinds, and these limits may be biological, economic, social, or industrial, or other.

The question that I am interested in at this point is, is there evidence that any of these limits are being approached or have been exceeded; and if not, how are they likely to first show up?

I just throw that out as an open question. I would be interested in your estimation of when we know we are in trouble.

Dr. Meadows, why don't you lead off.

Dr. Meadows. I regret the shade of meaning which has been assumed by the phrase "limits to growth." The phrase is used to imply a situation in which we will suddenly wake up one morning and discover to our surprise that after centuries of unfettered expansion we are suddenly hitting some absolute limit more or less as a car runs into a brick wall.

In fact, the limits are diffused in a social system as complex as ours. The limits impact on all aspects of our society and their pressure mounts slowly. Important limits are already exerting pressure on the population and the economic expansion in this country.

If we were to be attentive, each of us, as we go through our daily lives could list 100 ways in which the number of people, the amount of economic activity, the scale of energy use and the level of material consumption in this country decrease our quality of life. The list would include items that range from the relatively trivial aspects of trying to find a parking place to the very great difficulties engendered by sky rocketing prices of food, lumber, housing, and energy.

All of these things are related to growth. All of them are manifestations of pressures which will inevitably rise when you have a growing population in a finite area. Some will admit that demographic limits are present only when the population is declining from lack of basic nutrition. We need a more refined view of that. We need to think through the goals we hold out for our population. A start toward this end was made by the Commission on Population Growth and the American Future. Then we must determine what level of the population and economic activity are consistent with those goals.

Some people who have given this careful thought have decided that the quality of life in this country is already declining in important ways. The social services available in some areas, the access to natural amenities, the level of personal freedom and security are declining because of the growth that is already going on.

This gradual onset of more and more restrictive negative pressures is what poses a very strong challenge for our legislative branch. There is not likely to be a sudden threshold, a sudden explosion or collapse which will trigger wide scale concern. Rather we are now in a period which will see a steady erosion of the material and social aspects of life in this country. Personal freedom is declining both under law and with respect to discretionary resources. The quality of the environment is deteriorating and so forth.

The limits are active today by almost any standard. They are causing a deterioration in our life. They will undoubtedly continue to do so as population grows and as economic activities increase.

The only answer to the question "when will we meet the limits?" is "we already have." Corrective action today seems a little bit late, but it is better than waiting until tomorrow.

Mr. Dingell. Dr. Frosch.

Mr. Frosch. In my mind there are clear indicators of having reached certain kinds of limits to growth in particular areas in major U.S. cities, where I think the social pressures, if nothing else, are beginning to indicate that we have reached some kind of a very difficult point. Whether it is a limit is a question, but at any rate a point at which living in some cities has gotten in many quality ways progressively into difficulty. Certainly the environment in the more restricted sense of pollution has gotten to be a very serious problem.

Nevertheless, there are other parts of the country where I think the local people would feel that they have not yet reached their limits to growth the size and complexity they would like to get to. We are back with the problem of an aggregated model which can tell certain things in the overall, but if applied as a guideline to what to do, might apply well in some areas but create difficulties and injustices in another area.

There is a problem of growth, where and for whom, that has to be met with, and that is one that we are really just beginning to understand the complexity of.

Mr. Dingell. Gentlemen of the panel and members of the committee, the Chair notes with regret that we have two buzzers. There is an amendment to be voted on the House floor.

At this point the subcommittee will recess while Mr. du Pont and I go over to the floor and respond to the call. We will be back probably within 15 minutes. We do express our apologies and it will be necessary for us to recess the committee for that period of time.

If there is no further business to be transacted at this particular minute, the subcommittee will stand in recess for a period of about 15 to 20 minutes.

[Brief recess.]

Mr. Dingell. The subcommittee will come to order.

The subcommittee continues its study into the problems of growth and its implications for the future.

Mr. Potter. Dr. Frosch, you just finished raising what is a not uncontroversial point and I think Mr. Salyer wanted to say something about the question of how we know where we are.

Mr. Salyer. Well, I guess I wanted to make a couple of comments, somewhat general, but I hope related to the subject.

First, we should remember that the aggregate effects we perceive as approaching limits of one kind or another, are often the products of individual choices that are made, sometimes in industries or in institutions and having far-reaching effects, sometimes personal with more limited outcomes.

In the case of the population area, as in many areas of consumption, we are talking about total stresses that are the sum of individual choice.

It is important to look at the situation within which individuals choose between a variety of courses of action that are open to them.

One factor affecting the choices an individual makes is education. That people understand what aggregate dangers exist, and how close we are to certain limits, is an important and neglected element of the educational process.

A second critical factor is the environment within which an individual makes a choice, and a key part of that is the availability of real alternatives.

In the matter of automobile consumption I think this means having available and understood the alternative of smaller automobiles.

In the area of population choices it means, in part, having a range of contraceptives available.

A third factor in an individual's ability to choose is the knowledge and understanding of what the results may be in taking one course of action as opposed to another. In the matter of planning one's family as opposed to not planning one's family the knowledge of the costs of children, the advantages and disadvantages of spacing, and so on are important.

I think a fourth component in the capability to choose is the individual's ability to actuate a choice. Once one sees the value in making a decision, understands the range of opportunities, and settles on a single course of action, psychological or economic barriers may still stand in the way. If one is not able to carry out the required actions, then it does not make any difference whether he understands that there is a preferred course of action.

In the area I am most familiar with, that of choices regarding family size there are many, many components to this and one is very much a psychological situation.

If people do not feel they have a stake in their personal future as well as a collective future of the Nation, then I think you can expect less than full capacity on their part to act out a choice that is in their own self-interest as well as in the interest of the larger society.

What I am suggesting is that our Commission recommended as the proper national goal, actualization of freedom of choice. As we surveyed the range of policies and as we assessed the consequences of growth we concluded that the way you reach a stabilized population is not by passing a national goal that we stabilize the population but by creating a climate, an environment within which individuals can make informed reproductive choices.

I think that how you create that kind of climate is the kind of thing that lawmakers should be concerned with: the clarification of options; the removal of barriers to choices that we believe are in our society's best interest; and the support necessary for individuals to make thoughtful choices and act on their preferences.

I have tried to point out what I think are some approaches to opening that freedom of choice in the area of population. Other components of "growth," I believe, should be similarly addressed

Mr. DINGELL. Gentlemen, you will note the distress on the face of the present occupant of the chair. I will have to recess briefly with appropriate apologies again.

Our Clerk informs me it is a vote on final passage of the bill. The committee will stand in recess for approximately 15 minutes.

[Brief recess.]

Mr. DINGELL. The subcommittee will come to order.

Mr. POTTER. Dr. Frosch has a reaction to Mr. Salyer's remarks.

Dr. FROSCH. Thank you, Mr. Chairman.

I was somewhat bothered by what seems to be the assumption in Mr. Salyer's comment to the effect that given information and selective

choice individual rational choices will automatically lead to a set of decisions that would be rational for the larger aggregate.

At best, that is likely to be true if everybody perceives themselves as having the same problems, but it seems to me that one of the difficulties is that people in different parts of the country and different parts of the world see themselves (and perhaps really do have) somewhat different problems from each other. Their perception of how to solve their own local problems or personal problems or regional problems may be different than a perception of how to solve the world's problems.

For example, they may have short-run problems of personal survival in a region that lead to solutions that are antithetical to the solution of a larger problem: is local problem solving always a good contribution to larger aggregate problem solving?

It is like the example I gave this morning of some countries who simply feel they cannot wait to solve their own problems in the short run, because they simply won't survive as a people to the time when major world catastrophes that they are asked to contribute to the solution of will occur. When the problems are distributed in a nonuniform way, then the solutions may come out to be nonuniform, and not necessarily in a way that can be aggregated very well.

When people have different problems, individual rational choices may not produce a consensus on solution.

Now, we might say that if they understood both time scales and both sets of problems perfectly, then we could find some solution that would accommodate both social problems, but it seems to me it is not automatically the case.

It might take some doing to harmonize the problems in the sense that the solutions to those problems could also be harmonized. It is a complexity of problems.

Mr. SALYER. If I could make a quick response. I may have seemed to be waxing philosophical in that last statement.

What I was attempting to do was get down to the crux of the matter and to return to what Dr. Meadows said this morning about the components to our growth situation as being, in part, demographic; in part, material consumption; and, in part, service consumption.

I was talking from the perspective of one who is involved in trying to find some solution to the demographic piece of that growth problem and also speaking from the perspective of one dealing primarily with the domestic situation. With those qualifications I would say there is a certain happy circumstance in our domestic situation where the sum of the individual self-interest does seem to correspond to what is in the collective interest of the United States, if individuals are able to act out their reproductive.

The larger question you raise—whether in other situations informed individual judgments, taken collectively, are in the society's best interest—is the classic dilemma of political theory and of government in general.

I would maintain that at least in a democratic society we have very little choice but to look at the complicated problem you raise and ask, how do you clarify options and choices, alternatives, both for individuals and for the society, in such a way as arguments can be effectively marshaled to encourage an enlightened view.

I think that is what we are about here today, trying for each component of growth, mentioned by Dr. Meadows, to lay out the alternative courses of action and to assess how, in an intelligent way and a way consistent with our values, we can encourage a course of action that will result in a collective good.

I suppose it comes down to where one fits on the political spectrum as to how much confidence you place in the intuitive judgments that people will make when confronted with certain information or certain choices.

I may be a bit more confident and a little bit more optimistic about the way people will decide than some others.

That optimism is only warranted if we consider better ways of presenting alternatives so as to point up alternatives and necessary short-run actions.

I would be interested in Mr. Heller's observations on how this may be done on a State level as well as at national and international levels.

Mr. Heller. May I respond?

Mr. Dingell. Yes.

Mr. Heller. I think what we are talking about or what I am concerned about is how the Nation goes about addressing these issues and I gather this is one of the central concerns of this committee in this hearing.

Mr. Dingell. You are addressing yourself to the institutional problem, the structuring of institutions to arrive at proper decision making.

Mr. Heller. Right.

In my view, what we are talking about is a national planning mechanism.

Now, whether it is a superplanning agency or simply a process that we can understand, it is nevertheless, a national planning mechanism.

I think we are generally agreed that we do not now adequately address ourselves to these issues.

It seems to me that there are certainly three or four basic requirements for getting at these issues. First is information, the kind of thing that Mr. Salyer has been talking about, finding out where we are, finding out what are the alternative strategies available to us and even testing new concepts, if necessary.

It is my view that this sort of informational mechanism, whether it is an environmental institute such as Mr. Potter mentioned or something else, that informational category would have to be accessible not only to the executive branch but to the Congress; that its findings should be visible and that it might well publish regularly proposed alternative national policies.

I think that a second requirement of a national planning mechanism is a strong Executive Department responsibility within this field with the President in charge and involved.

Third, and this gets to the area of carrying things out, is a closely tied-in budgeting process, not only as an aid to congressional budget activities but really to force an administration literally to put its money where its policies are.

The fourth requirement in my view is that an information gathering/budgetmaking or a planning/budgetmaking mechanism at the Federal level has to be conceived as a part of a national system of decision making, including State and regional elements.

Mr. HUNT. May I pick up from there?

Mr. DINGELL. Yes.

Mr. HUNT. Going back to your original question that Mr. Potter brought up and perhaps reaffirming some other comments that were made before, I think one of the major problems that we have in this field is the absence of an adequate welfare accounting system within this country.

The lack of such a social accounting system has led us into a number of noneconomic traps. Where a man is permitted to invest, for example, $1.20 and get back $1.50 and hence a $0.30 personal profit without recognizing that he is costing society as a whole an additional dollar in hidden incremental costs we have a case of poor public decision making. Until we are far more thorough in accounting for these third party, external diseconomies, or hidden costs, call them what you will, our decision making on these issues of growth will be at best, weak and imperfect.

Even without such a methodology of analysis I think there are a number of indices showing that we are reaching the limits of growth in certain fields.

I was born and raised in New York City and live on its outskirts today. There is evidence that the social systems in this microcosm have been breaking down or deteriorating for the last 5 to 7 years.

For example, ask any citizen of the area what the phone service is like and which direction it seems to be heading.

Mail, another communication or social service, has been getting much worse in terms of both pickup and delivery for all the efficiency and cost savings that are claimed.

Electrical energy, again within the category of social services, shows a simultaneous increase in costs and decrease in reliability. And then there is the tragic case of education.

On a national basis, we are, as has been discussed, getting signs on resources in terms of rising prices. As mentioned, food, wood products, energy, and indeed labor prices are rising and are expected to continue to rise for the forseeable future.

To me, all of these factors are indicators that we are overstressing our system.

Turning to Mr. Heller's comments, he brought up the necessity for the development of new information, data, and knowledge.

I think rather than just distributing it to the Congress and the Executive there is an obligation, in this country, to disseminate that information to the public, particularly to the adult voting public in this country.

The word is not now getting out. No one, including our own executive branch at this point is making aggressive effort to present, the true choices, the alternatives in a futuristic sense to the public itself. Until that is done and pressure is built from the constituency of the Congress itself, we will not be able to approach these problems in a rational manner.

I would add that to your words, Mr. Heller, if one does develop a think tank or special studies group, a strong effort be made to make the conclusions and recommendations of that organization broadly and widely available to the general public.

Thank you.

Dr. MEADOWS. Mr. Chairman, the aspect of the growth issue which makes it so difficult to deal with in a form like this is that it demands a time horizon far beyond that which is normally present in the conduct of our daily affairs.

I can well imagine those who may examine the evidence offered forward today asking why it is we should suddenly assume our economic system and technological powers will not take care of these problems. We believe that they have always done so in the past. Why should we suddenly be worried about the long-term consequences of growth when such concern has not been necessary during the last 200 years of our Nation's history?

Those are important questions. It is fair to expect that they be answered before one can expect new approaches to these issues.

I suggest that we actually have entered into a new period, one which does demand somewhat greater compromise among our various goals. Several facts may illustrate my claim. This country was unusually well blessed with natural resources during the early periods of its history. During some period of its 200 years' existence as a nation the United States has been the world's major producer of practically every natural resource. Of course, we are still the world's major consumer of almost every natural resource. Because of our incredibly bountiful endowment and the very small number of people who first migrated here as we have gone through a period in which natural resources constituted essentially no constraint whatsoever on our growth, land area, water, minerals, and fuels were all present in quantities unprecedented in history. More important, such prodigy will never exist again either here or abroad outside the Soviet Union.

We were able to provide for essentially all our own needs. Therefore, we were freed from any constraints by others on the flow of natural resources into our economy. Today, of 36 critical resources required by our economy, about 30 are imported wholly or in part. The trends are toward a rapid increase in our dependence on overseas supplies. In contrast, the U.S.S.R. imports portions of only seven materials required by its economy.

This morning Mr. Brown portrayed a number of factors which have altered the food situation. Land availability is also altered. In the siting for power reactors, the location of refineries, and so forth we are beginning to find that there simply is no land on which to locate those activities without compromising the goals of some individuals or citizens.

Until very recently we still essentially had a frontier that could be exploited. Now we are faced with a new situation.

More difficult than the new resource constraints is the rapid rate of change facing our institutions. Our demand on all resources currently doubles within a period of one or two decades. The sheer magnitude of the growth that must be managed does confront us with a new situation.

There are suggestions by many that technology of the economic system can guard us through a period of transition. There is no empirical basis for that statement since we have no historical experience with a period of transition from growth equilibrium. Moreover, there is much knowledge that suggests the contrary is true. My background is in system control. A fundamental tenet of control theory is that systems will achieve their goals only if the planning horizon is somewhat commensurate with the time delays in the system.

In our national socioeconomic political system we have time delays of 30 to 50 years or more. It takes that long to alter the nature of our power system, to stabilize our population, to assess the impact of environmental pollution on the weather and so forth. Yet the planning time horizons of our industrial and political organizations are very short, a few years in most instances.

If each of us were riding in a car where the driver had his foot firmly pressed on the accelerator, where the driver was so intoxicated that it took him several minutes to respond to perceived threats on the road, and where he was guiding the car by looking out the back window, I think none of us would expect to arrive at our destination. Unfortunately, that analogy is a very appropriate one for this country. The economic system and new technologies will be helpful. But neither economic nor technical institutions are immune to the consequences of rapid change, short time horizons and very long implementation delays. Thus they must be augmented by formal efforts at longer term planning.

There has been one or two references by our panel to the word "planning." I know there is a great tendency in this country to consider national planning as something done only by Communists. Many would suggest that it is an activity not even to be considered in the context of our free nation.

In fact the majority of the countries which employ long-term planning are not communistic. It is time to break down this prejudice.

It is also time to recognize that our country has moved into a period where trade-offs are so difficult, and changes over time are so enormous that we must develop new planning institutions to augment our current legislative, legal and executive institutions. All of these do have the flexibility to respond in a constructive way to the inputs from planning institutions.

Each of you are required to pass daily upon matters of energy, welfare, policy, environment, foreign trade and so forth. There is absolutely no rational basis for choosing among the alternatives that confront you until this country has a longer term image of its long-term feasible options and of its basic objectives.

There is no way to choose among alternative energy policies that will take 30 years or more to implement without an understanding of our likely goals and resources 30 years from now. Basing these decisions on short-term considerations will certainly fail to meet our long-term needs.

In addition to the other words introduced into the discussion today, "planning," the attempt to set long-term goals and allocate resources for their attainment, could also become a part of the conversation about growth. Without planning, without a systematic effort to think of the tradeoffs we simply do not have the facilities to deal with the food, energy, urban and other issues that have been put forward today.

Mr. Salyer. I would like to add a footnote to that.
To take off on Dennis' analogy of the drunken driver looking in the rear view mirror, the question comes to how much effort you will devote to develop an automobile that can be put on automatic pilot and controlled from some central guidance point, and how hard you are trying to sober up the driver to a point where he can drive the car.

No one would deny the need for the longer range planning, but I think we have to also ask where we put our emphasis and over what time horizon we stress various parts of the solution process.

One reaction is a centralization of planning authority and power. That is true when you are speaking on a local level about the inability to make decisions affecting metropolitan concerns because of overlapping jurisdictions making it possible for any separate jurisdiction to make long-term planning choices.

It is also true when we talk about States and it is true on the Federal level. Another alternative is try to extend the time horizons of the individuals and to enhance their ability to cope with uncertainties and rapid change, and we heard talk about that today also.

Mostly, it takes the form of education. I think you can translate aggregate, long-term problems into more individual, micro concerns. This is an area that is promising but that we know frightfully little about.

A few economists around the country are resurrecting the concern for household economics, asking what is the cost to an individual family of certain changes, whether it is the addition of another person, another mouth in the family, or whether it is the cost to the family in taxes of another warm body moving into their State or city.

This kind of analysis is in its infant stage and needs to be developed in a way that enables us to more skillfully translate aggregate concerns into individual terms.

I think the other alternative that I think most of us are rejecting is to rely on individuals' short run perceptions of what is in their best self-interest even with admittedly inadequate information. This approach relies on a concept of human nature that, under certain stress situations, people will sense that something is wrong and that they will take their required actions.

Doubtless, it is going to take a combination of all these approaches. But as we talk about planning authority we should also be dealing with how to increase the time horizons of individual citizens, and how to translate long-term concerns into individual terms.

How can you begin to have an individual understand that having 40 million in the State of California by the year 2000 is not in his best self-interest, other than by saying gosh, your block is certainly crowded. That is not going to work. If that is the way we sell these ideas we will produce all sorts of perverse outcomes in planning that may put us in a situation as bad as would result from the absence of planning.

Mr. Potter. Dr. Meadows, your point on our being apprehensive about planning in this country is well taken.

I wonder if it is an apprehension of planners or an apprehension of people executing the plans that are drawn by the planners.

This may be a useful dichotomy because what we are suggesting, and I take it what you are suggesting, is that we need a much clearer

perception of the alternatives and what it would cost us to reach any of those alternatives and that what actual steps we are going to take in order to reach the alternatives that we choose is a second order judgment.

Dr. MEADOWS. The dichotomy you have drawn is a useful one. It is useful to recognize that our apprehension about planning derives from a rather narrow image of what planning might entail in our country. It is easy in talking about national planning to conjure up a vision of a small group of men deciding what is best for the country. We rightfully have a reaction against that image. Such a mechanism could not work in the best interests of the majority in our society.

Planning is intrinsically nothing more than the process of analysis, data gathering, and choice which can take place at any level of government or the private sector. The planning process that would be most appropriate in our country would be one that takes place in a central location to set certain standards, both ethical and procedural in nature and agreed upon by the majority, so that at each locality, there could be a mechanism for performing analysis and choice with a longer term perspective.

If planning were conducted in a manner both pluralistic in nature and specific in form, so that its underlying assumptions are subject to criticisms by those affected, then it could come to play a very useful role in our society.

Mr. DINGELL. Dr. Frosch?

Dr. FROSCH. I agree with that point. It seems to me there are two reasons for suspicion of planning.

One is a feeling that planning means an erosion of freedom. Of course, it does, but it might be a voluntary giving up of freedom in certain small ways in order to gain major advantages.

However, there still is a feeling that plans then become a constraint that you may or may not want to allow.

In situations where it is clear that the combination of all freedoms require planning, they are likely to combine and do planning, but if it is not conceived that they are in trouble and planning is opposed to freedom, Americans are likely to opt for freedom.

The other problem is I think suspicions as to whether planning works, whether, in fact, we have a methodology that makes it possible for the results of planning to be an improvement.

I would argue that there are some real problems in planning methodology. At least one of the problems is whether a plan becomes a static plan so that you are bound by it long after circumstances may have changed and made it a poor plan.

That poses a very severe methodological problem because it means you have to produce a plan which is capable of change as circumstances change without having to be entirely redone.

A sequence of plans that are partially carried out has sometimes been worse than no plan at all. That is not to say that they are going to be worse than the plan which is constructed to be flexible, but I am not sure we really know how to construct those plans.

Mr. DINGELL. Mr. Heller, and then Mr. Hunt.

Mr. HELLER. Mr. Chairman, I would feel that the warnings that we can sound against the dangers and difficulties of planning could continue this for a long time.

However, I must support Mr. Meadows' basic thesis that the United States has an obligation to devise ways and means of coming to grips in an orderly way with some of the many new problems that are forcing themselves onto the scene from several directions.

I would make one specific comment on one of his points. He seemed to emphasize the need for regional planning centers of various kinds, which I would certainly heartily endorse as one of the things that I was talking about this morning.

At the same time, one of the things that we learned in attempting to construct the "California Tomorrow" plan was that you really cannot plan responsibly at the State level without comprehensive guidance at the Federal level, and comprehensive planning of a kind which I think probably has not been contemplated seriously at the Federal level.

Mr. DINGELL. Is it not true whenever you run into a broad national problem that you have to have a measure of standardization across the country then with the maximum amount of local and State discretion and judgment-making capacity, that the circumstances would justify?

Of course, as Mr. Potter reminds me, you run into the same problem as opposed to national actions where you have problems which are international in character.

Mr. Hunt?

Mr. HUNT. I just would like to make one comment, that the actual detailed planning be handled on a local, suboriented or geographically oriented basis, with a top group coordinating, organizing, and providing the parameters for this planning.

I heard evidence of such unintegrated planning this morning when we were informed that the AEC has just cut its estimates of this country's petroleum requirements for the year 2000 by some 20 or 30 percent. I cannot remember the precise figure, but it is not important. The question is, on what basis did the AEC develop this new estimate, and do they recognize the full implications of such a revision, beyond the consideration that they may have to build more new plants? Have they really examined the alternatives; have they discussed this and factored their new thinking into the plans and projections of the Bureau of Mines? If they have not, I can't take their analysis and planning very seriously.

It has been the absence of coordinated lateral transfer of information, mentioned by Dr. Meadows, that has plagued such planning in the past.

In light of this I would like to make a strong case for a central governmental planning agency that may not be involved in the absolute particulars, but at least handles the coordination, of the subelements. Without such a group, I think we are likely to perpetuate the suboptimal choices that have characterized a lot of our past decisions.

Mr. DINGELL. I think you make a very good point.

Mr. HUNT. If I may continue just for one more point.

It occurs to me that, and perhaps this is stepping outside of existing jurisdictional bounds, but that the Congress, it would seem to me, which in toto has a greater longevity and better time perspective than the executive branch, should manage this coordination function themselves.

The President is limited to two terms within the executive branch, but the Congress itself has a more distant time horizon than I believe the executive branch does.

It would seem appropriate that such a planning agency work through the Congress as opposed to working through the Executive.

Mr. DINGELL. Mr. Hunt, we are always happy to hear that the Congress should do these things. I think this is our constitutional function.

Dr. Meadows?

Dr. MEADOWS. It might be useful to offer a set of concrete statements that describe the process of planning and illustrate the factors involved if we should begin to base some of our decisions on the outputs of explicit planning.

Our political and economic institutions already make decisions. Those decisions have to be based at least implicitly on some assumptions about the long term. If we do not plan explicitly, our decisions are based implicitly on very simple projections. These forecasts are essentially that our goals and resources tomorrow will be more or less like those today. That image of the future may be the only one we know to be false. While we cannot predict the future precisely, the more explicit approach to forecasting and planning could hardly help but improve over the current situation.

Planning is, first of all, a process that involves identifying potential future problem areas; for example it may concern the availability of energy over the next 30 years. Then one must gather data on society's values, resources, technical capabilities, physical limits, and so forth.

The third step in planning involves analyzing those data to understand what the range of feasible outcomes actually are. The first three steps in the planning process involve operations of tasks we have been dealing with that could be delegated to some national institution.

Having determined the feasible possibilities over the timespan of interest, it then becomes necessary to choose which of those are most in consonance with our underlying goals. That choice is a function which is political in nature and which cannot therefore be delegated to a group of scientists or computer programers outside the mainstream of our political system. Choice of that sort is the specific objective and responsibility of the Congress.

Having made that choice, perhaps through consultation with the executive branch, it then becomes necessary to put into place those institutions, those laws, those executive practices, those standards which will move us toward the alternative we have chosen. That is the function of the legislative and executive branches.

Our Government already performs each of these operations at least in a rudimentary and uncoordinated fashion. The difficulty is that it is often done under extreme time pressures by people preoccupied with only certain salient aspects of the total problem and in an environment where it is very difficult to identify all of the alternatives.

These early stages of problem identification, data gathering, and analysis should be done in a manner which makes the result highly accessible to those concerned. It should be done in an environment which leaves some time for creative thinking and for checking the accuracy of all the factors that are taken into account.

I do not know of an institution available to Congress on a full-time basis that can provide those three inputs from problem identification, data acquisition, and analysis systematically for the broad range of issues on which you have to decide. Your overburdened staffs and special-interest groups, and the current sources for those first three products of planning, our country needs, deserves, and can obtain much better analysis than is currently available. There are already models abroad of institutions that could be adapted to our needs to provide a much more useful basis for the kind of decisionmaking with which you are faced.

Mr. Dingell. Of course, Doctor, is not the last problem you have alluded to one of the major problems with which we are beset; and that is the incapability of deriving information into digestible form upon which you may rationally not only begin the decisionmaking process; but, equally important, begin to understand and appreciate the questions—not the answers, but the questions—to be answered to get the answers and also to arrive at an institutionalized type of decisionmaking and problem solving?

Dr. Meadows. Nothing we have discussed today is easy. However, to say that something is difficult is not to imply that it is unimportant. In fact, the contrary is often true.

Mr. Dingell. Is not really our first step legislatively in the Congress to begin to furnish ourselves and the Executive with the mechanism for getting and analyzing the information we have available as a stride toward arriving at an appreciation of what the questions are, how we get the answers, what the institutional-type decisionmaking devices happen to be? But in this area I have a feeling we do not know what the questions are; much less what the answers are.

Dr. Meadows. We have identified a number of critical questions today. Many of them are not being addressed in an effective way by anybody now in our National Government. While there is not yet a full appreciation of all the issues involved in growth, there are already many questions that could be addressed.

We will never completely solve all of the U.S. problems. We are in a dynamic situation, our goals, our capabilities, and our resources are continually evolving. But in each area of the problems cited today we could now with established data, current theory, and available techniques make very substantial progress. It would require only that we spend a relatively small amount of money addressing these longer term issues.

We spend something like $70 billion a year in this country on national defense. What is the justification for that? Well, so far as I can understand it, we have a national defense establishment so that we will be free at all points in time to pursue our national goals even when those goals conflict with the objectives of other countries. If we spend $70 billion a year to pursue our national goals, how much should we spend trying to identify what those goals actually are?

Whatever the figure should be, it's a fact that less than a thousandth of what we spend on defense is available for systematic analyses of what our long-term goals might actually be.

There is simply no consistent, generally shared image of the long-term future of this country. Each executive department may budget 5 years ahead, but many independent budgets, when combined, do not form a consistent image of where the country is headed.

Mr. DINGELL. Dr. Frosch?

Dr. FROSCH. I would like to add a kind of institutional procedural point to this.

The idea of an analytical group that will go off and produce a set of choices which will then be brought before the Congress to be acted on subsequently by the political process—judging from my experience with that kind of analytical group—is almost certain to be a failure. It will be a failure because the group itself cannot analyze everything; it will have to make some choices as to what it analyzes and what the objectives will be. They are likely to get devoted to some particular direction that they think up themselves, so that almost inevitably when the results of such a group come before the political process there is a certain amount of "pick a card, any card," but the card is being forced on you if you are not careful.

Unless the political decisionmakers are somehow involved with the group of analysts over the period of time in which they are defining what the meaning of the problem is, and what the alternatives are, and even to some extent how the alternatives are to be treated, then the planning process would assume too much of the role the political part of the process and may not be very helpful.

Whether it is the Executive or the Legislative that is to use the results of planning, it will have to be a part of the process from the beginning, or you will too frequently discover that the problem that was analyzed was not really the problem that you thought you wanted to have looked at, or that there are alternatives that are obvious from the political vantage point that were not included in that analysis.

There is a continuing realism that is required by this process that I think can be provided, and I think it is an important part of the process.

Mr. SALYER. There is one such institution, the National Commission that has been used for joint congressional administrative analysis.

For a variety of reasons their reports, as Congressman McCloskey pointed out this morning and Senator Kennedy pointed out a couple of years ago in hearings, are treated like a bunch of jimminy-crickets chirping in the ears of deaf people, both public officials and the public at large.

We come right back again to the issue of how is it that you communicate these concerns.

I guess I would argue that something like a commission makes sense, but with an ongoing life. Commissions are short run and have limitations because of that. But with continuing input from Congress and from the Executive, and if enough teeth and enough responsibility were built in so that its reports and the alternatives put forth were responded to instead of ignored, then it could serve a useful function.

I think in looking for examples in other countries, it is important to think about one fundamental constraint on planning in this country. That is, that this is not a homogenous society and the conflict between the need to do better planning and the groups in our society clamoring for greater participation has by no means been resolved. And it is a dilemma that has to be taken account of as any mechanism for planning is discussed.

More than how we analyze data is at stake. We must ask how we set our goals, how we decide what ends there are worth pursuing by whatever policy means. As we approach the 200th anniversary of the Republic, we still have not dealt with this very well.

Mr. DINGELL. Mr. Mills?

Mr. MILLS. I have no questions, Mr. Chairman. Thank you.

Mr. DINGELL. Mr. Rountree?

Mr. ROUNTREE. Essentially what I think we have been saying for the last few minutes is that what is one man's fact is another man's fancy.

What one man believes is a logical choice, another man may oppose as being the worst possible choice and what you are saying is that existing institutions do not have the capability to, in a cohesive fashion, reach a decision in setting long-term goals, objectives, and then translate these into positive action.

Thank you, Mr. Chairman.

Mr. DINGELL. Dr. Meadows?

Dr. MEADOWS. Responding to Mr. Rountree's point we should recognize that there are immediate and concrete problems that demand our movement toward longer-term plans.

I will describe three for you. I recently spent some time with a senior official from the Economic Ministry of Japan. He expressed a strong desire on the part of his country to participate in discussions with the United States and other countries about longer term resource imports.

Japan is highly dependent on materials from abroad. Europe and the United States are growing increasingly dependent on imports. Without much imagination we can look forward to a period when the United States, Western Europe, and all other industrialized countries, save the Soviet Union, are competing for common resources. It seems to any rational individual, any rational country, that it should be possible to sit down together, to find common objectives, and to serve those objectives through agreements and the development of new technologies.

I asked my Japanese friend how it would be possible for the United States, with an effective planning horizon of 2 or 3 years, to find common goals with Japan which now has a rather well-developed 20- to 30-year plan for securing resources.

I am sure each of us has had the frustration of trying to reason with a child who has focused his energies on securing the satisfaction of some short-term need. If I were approaching resource conversations from the perspective of Japan, I would feel very much like an adult who is willing to defer short-term gratification to assure something more enduring in the future, but who is negotiating with a child interested only in the present. Of course, this problem is much more serious than the conversations with a child. Over the next 5 to 10 years we will establish patterns of resource use that will dominate the globe over the next several decades. I am very pessimistic under the current circumstances that those patterns will be established in a way conducive to the orderly evolution of our economy.

Lester Brown pointed out the impending Law of the Sea Conference. It is manifestely in our best national interest over the short term to avoid any kind of commitment to other countries on utilization of fish resources. Over the next year or so we are likely to have more fish available to us if we avoid any kind of conservative measures entered into

with other countries. It is only when we adopt a 5-, 10-, or 15-year perspective that it becomes in our best interest to sacrifice short-term harvests for the longer term stability of that important source of protein.

We are going into negotiations now with Europe on fundamental issues of trade and resources, food, and so forth. Again, I see almost no hope whatsoever of emerging from those negotiations with any constructive agreements based on long-term interest of both sides unless we have some mechanism for placing our trade in the context of a plan for the evolution of our economy over the next 10 or 20 years.

Those are just three of the concrete issues that we will face over the next year. For each of them we definitely need the inputs which will only be available from a longer term planning process.

Mr. Dingell. Of course, I would like to address this problem from two standpoints.

As you are aware it has been this subcommittee I suspect more than any other in the Congress which has tried to devote itself to a rationalization of the problem and to the direction of seeing to it that we have the mechanism that would provide us with the information and the data in a systemized, understandable, usable form upon which these long-term resource environmental and if you wish, economic judgments could be made.

It has been this subcommittee again which has moved toward even a modest kind of internal restructuring inside the Congress towards this end with modest successes and I suspect modest failure.

But the problem that really concerns me here is what perhaps are the mechanisms in the institutions which we will ultimately have to evolve to accomplish the kind of long-term resource management, resource utilization, the economic devices that you have been addressing yourselves to now, Dr. Meadows.

Dr. Meadows. My answer will be brief because I suspect that others on the panel have a better basis for response to that question. I think we must frankly admit that we do not fully know how to answer your question. At the moment we can only perceive components of the solution. But those components are sufficient already to make possible some bold and useful new initiatives.

I could conceive of an analytical staff funded by the Congress and given responsibility to address issues of a broad social concern must be faced over the next 5 to 15 years.

It is easy enough to identify in transportation, the environment, energy, cities, land use, income distribution and many other areas, factors which will continue to generate short-term pressures and crises that will be called to the attention of Congress.

An analytical staff somewhat dissociated from the short-term pressures but funded on the basis of its long-term utility could substantially enhance Congress ability to respond to these problems.

Mr. Dingell. Dr. Frosch?

Dr. Frosch. Well, I think I would like to go back to a slightly broader philosophical point that has been bothering me through this whole thing.

What we are really saying is that somehow if we take a broad enough look we will have some kind of capability to predict the future and construct some kind of plan that we can then carry through:

I am a little worried about the loss of the word and of a measure of flexibility.

Our history of capability to do any long-term or even short-term prediction is poor; I think it is poor for good reasons. Therefore, anything we propose to carry out had better be such that it is capable of change, that it is resilient, and that we intend to change it as circumstances change throughout.

Again, I think that has to be reflected in the institutional arrangements that one sets up.

I am not sure that it is completely bad that we tend to react on a short-term basis and I am not sure that we are completely lacking in long-term perspective even though it is not as explicit as it might be.

Certainly, in the context of the defense planning which was referred to, there have been continuous attempts over the past decade to base it on long-term perspectives, and it has become perfectly clear that there are not only long-term perspectives, or at least that every one that has been chosen has turned out to be wrong very shortly thereafter. Fortunately, in most of those areas we have not succeeded in basing our planning on long-term perspective or we would have been turning up half-built things every instant. We have, in fact, had to do a good deal of that nationally.

The question I have is, how can one engage in a rational planning exercise—and I think you must engage in one—without losing a lot of resiliency in the actual plan and in the carrying out of the plan.

Mr. Dingell. Dr. Meadows, I think you wanted to respond and then Mr. Heller.

Dr. Meadows. Dr. Frosch's concern for flexibility is one which I would strongly support. However, I would not leave unchallenged the implication that the current system is somehow perfectly flexible.

One needs only to look at our response to the energy crisis for example to perceive the awful inflexibility and lethargy of our economic and political institutions.

Mr. Dingell. Excuse me. Dr. Frosch is in agreement with you.

Dr. Frosch. No, I do not think the current system is flexible, but I am worried about some of the propositions that I have heard, which sound as if they might make it worse and not better.

It is possible to make it better, but whether it will automatically work out that way, I am not sure.

Dr. Meadows. Well, it is possible to employ any tool of man so that it serves narrow interests or worsens the general situation of society. My assumption has always been that if we manage our affairs more explicitly—that is to say, by laying out our assumptions where they are subject to the scrutiny of others—we are likely to improve on the process.

Everywhere I look at our response to urban deterioration, crime, drugs, to the energy crisis I see evidence of gross rigidity and shortsightedness. Look at transportation. How much flexibility do we seem to exhibit under the current free market in response to the problems caused by cars?

Mr. Dingell. The Chair observes that we do not even have a mass transit system in this country.

Dr. Meadows. It would be very easy to improve the responsiveness of our institutions.

Mr. DINGELL. Mr. Heller?

Mr. HELLER. Mr. Chairman, I would like to be quite specific about what I would like to see in the way of institutions, not in complete form, but I would like to see a national planning responsibility in the Executive branch. I would like to see broad responsibility given there. I would like to see an annual publication or expression by that council or agency of national planning policies or goals.

I would like to see the annual budget reflect those policies, and I would like to see the Federal budget analyzed from that standpoint. There are advantages in such a visible procedure.

After all, we now have the Office of Management and Budget which I suppose with the White House staff is the national planning agency, but it is not a very visible agency.

The Director of the Office of Management and Budget is not even confirmed by the Senate.

Mr. DINGELL. You will be interested to know that that was a subject of debate on the floor today.

Mr. HELLER. How did it come out?

Mr. DINGELL. I understand that the President will have before him the question of signing or not signing the bill to confirm the Director and the Assistant Director of OMB. I will be interested in seeing whether he signs it.

Mr. HELLER. Well, I think this does go to the issue of invisibility and nonresponsiveness.

I feel that the planning responsibility in the Executive branch could involve the commissioning of the types of studies that we have been talking about, and I furthermore think that the national planning agency or council at the Executive branch, perhaps presided over by the President, could well make its findings and its studies available to the legislative as well as the Executive branch.

This kind of institutional arrangement does not solve all problems but it begins to get to the need for an across-the-board, open approach to some important ones.

It would not in any way preclude Congress from commissioning studies or creating institutes to help in its decisionmaking responsibilities.

Mr. HUNT. I will pass at this point. My points have been covered by Dr. Meadows.

Mr. POTTER. The witching hour is upon us, and the hearings are about to close up.

I would like to ask the members of the panel if we can use your services to help us structure the next inquiry that the committee is going to have to take in order to come to grips with this problem.

I would expect that if we can get the transcripts back from you soon. and I ask that you expedite your review of those transcripts, that we can have these hearings possibly out within a month or a month and a half. That is remarkably fast, but I hope we can do it.

We will be in touch with you and send you some more materials.

We have already sent you a summary of issues that we think might be appropriate for the later hearings, and questions that ought to be addressed within those issues, and we would ask that you take a look at those and correct them and make any suggestions that seem appropriate in areas of your expertise or interest. We also ask that you make

some suggestions as to people that we might contact for more extended hearings later in the fall. We will do all this fairly soon.

If we can use you, I can assure you that your help will not only be useful, it will be essential if we are to come out of this with the kind of output that I think we can produce and that you have, in fact been demanding that we do.

That is all I have.

Mr. DINGELL. Mr. Mills?

Mr. MILLS. Nothing else.

Mr. DINGELL. Gentlemen, the Chair thanks you for your patience, your attendance, and for your very helpful testimony.

The Chair does reiterate the request made by our counsel, Mr. Potter.

The Chair does advise that we will keep the record open for a reasonable period during which it is the hope and the intention of the Chair that each of you and that other interested citizens should have an opportunity to make submissions and suggestions with regard to the contents of the hearings today and also with regard to the future activities of this committee in this area as may be appropriate.

The Chair does advise that we would very much look to each of you because of your high expertise in this area to give us your counsel as to further activities by this committee in this area.

The Chair is, as you know, much apprehensive of the failure to ignore the problems of growth, the bounds of growth, and so forth.

In the past weeks, the committee staff has prepared a series of questions dealing with a number of growth-oriented issues. Last week, a revised version of this request was mailed to each of today's panelists, and we are asking them to review this and to suggest ways in which these questions may be best explored. Without objection, this material will be included in the record at this point.

[The document follows:]

RELEVANT GROWTH ISSUES

Prophets of catastrophe, their critics and basic governmental issues

- Limits to growth;
- International issues, including development of third world;
- National issues; and
- State and local issues, including inner-city problems.

Basic parameters of growth and technical considerations

- Population increase;
- Economic growth;
- Resource scarcity;
- Environmental pollution;
- Land use; and
- Adjustment mechanisms: market system and the "technological fix."

Outlook for Government action

- Treatment of growth issues by executive branch; and
- Implications of growth for Congress and for the committee.

LIMITS TO GROWTH

What are the constraints to growth on a worldwide scale? What are the costs of continued growth, and what are the costs of constrained growth? What are the short- and long-term implications of present growth trends and of constrained growth?

DISCUSSION

The publication of *Limits to Growth* by the Club of Rome and the publication of "Blueprint for Survival" in Great Britain reopened the debate on the degree to which economic growth and population increase are sustainable given the limitations of finite resource availability and finite capacity of the biosphere to dispense pollution. Both documents point toward catastrophe if growth is not limited soon.

Critics of these antigrowth spokesmen question the assumptions upon which the predictions of doom are based and point to the history of unrealized eschatological predictions as well as to the weakness of the predictive models themselves. Critics point to technological advances and the market system as factors making adjustment to changing resource availabilities less difficult.

The issues raised both by the prophets and their critics are worthy of attention because of their implications for public policy at all levels of government.

ISSUES FOR CONSIDERATION

(1) What is to be included under the rubric "growth"? Economic productivity? population? technological capability? standards of living?

(2) To what extent is growth sensitive to public policy changes?

(3) Assuming that the earth has finite capacities, what happens as the limits of those capacities are approached? Does precipitous decline result—as the authors of "Limits" assume—or will there be smooth, gradual adaptation of social systems? (See discussion of market mechanisms and technologic advance.)

(4) Are the problems described by "Limits" real and pressing, and if so what is the degree of their immediacy?

International Issues

Economic growth, population growth, and the issues which surround them are of critical importance to both developed and underdeveloped nations. Attitudes toward growth and toward the relative demand for resources among the developed and underdeveloped nations differ considerably. What are the implications of growth patterns around the world for U.S. policy?

DISCUSSION

For years growth, especially economic growth, has been the aim of most nations of the world. Only recently has it been seriously questioned. Developed nations aimed at growth to maintain or raise their already relatively high standards of living, and underdeveloped nations aimed at growth in order to survive. Booming increases in population, especially in the underdeveloped nations of the Third World, continue to reinforce the need for economic growth.

As world resources become more heavily burdened, the differences in demands placed on resources by the different nations will raise the already visible question of equity. Are some nations placing unjustifiably high demands on resources at the expense of others?

ISSUES FOR CONSIDERATION

(1) Do developing nations have any choice other than seeking to increase their rates of growth?

(2) Are developing nations receiving fair prices for their raw materials?

(3) What are the international implications of increasing demands for energy? Is the current U.S. energy problem strictly a national problem?

(4) What are the implications of multinational corporations on worldwide rates of growth as well as on growth rate differentials among the nations?

(5) What international organizations have studied and made recommendations on growth problems? What have their findings and recommendations been, and what are the implications of their work for U.S. policy?

(6) What is the status of international cooperation to deal with pollution problems?

(7) What are the implications of international growth problems for U.S. national defense and security?

National Issues

Is a national growth policy for the United States desirable, and what is involved in the formulation of such a policy? What should be the content of such a policy and how it could be implemented?

DISCUSSION

For a number of years writers from a variety of fields have been calling for the development of a national policy on growth. These calls have been made in several different contexts. Some have been aimed at economic growth, some at urban and some at population growth. Calls for a growth policy have reflected attitudes for and against growth, or they have called for more rational accommodation of growth.

Early on there were calls for growth into the western lands. Later there were calls for policy to increase the rate of national economic growth, to stimulate growth in the depressed regions of the country. During the late sixties there developed calls for a national urban growth policy—calls which eventually resulted in the Urban Growth and New Community Development Act of 1970 (title VII of the 1970 HUD act). More recently there have been calls for national policy to constrain economic growth and population increase in order to conserve scarce natural resources and to protect the environment.

The development of national growth policy has implications at all levels of government and for a variety of interests.

ISSUES FOR CONSIDERATION

(1) What should a national growth policy seek to achieve, how should it be formulated, and who should play key roles in the formulation?

(2) What impact could we expect a national growth policy or the lack of a national growth policy to have? What implementation mechanisms exist?

(3) What are the implications of plausible alternate growth policies for trade deficits, economic stability, full employment, industrial planning, tax policies, population increase and migration, environmental protection and resource planning, urban development patterns?

(4) How are Federal policies affecting growth at present? How can changes in these policies be expected to affect growth in the future?

(5) How will environmental legislation such as air and water bills probably affect growth?

(6) What are appropriate congressional responses to calls for the development of a national growth policy?

State and Local Issues

How are State and local governments and interests related to national growth issues? To what extent should national policy be an aggregation of state and local ("bottom-up") policy—as opposed to a centrally determined ("top-down") policy?

DISCUSSION

Whether growth policy is to be left in the hands of State and local governments or dominated by the Federal Government is a major question. (At least one bill was introduced in the 92d Congress to establish a federal agency charged with national growth policy planning, and national land use policy bills, which have major growth implications, received extensive consideration during the 92d Congress. Several bills have also been introduced during the 93d Congress). The answer to the question will be determined in large measure by intergovernmental structures established both by the Constitution and by practice. Political pressures at the various levels of the federal system will also influence the outcome of the question—even if it happens that the question is left unanswered.

Some efforts are being made now to implement State and local growth policy decisions. Oregon, for example, has shown interest in limiting its population growth and a number of localities around the country have curtailed some forms of new construction in order to limit growth. Some of these local decisions have been the result of conscious growth-limitation policies, and others have been in response to the overburdening of public facilities such as sewage plants. In some

95-852 O - 73 - 5

cases growth limitation policies have been labeled subterfuges to avoid the construction of low-and moderate-income housing in local jurisdictions.

On the other hand, many jurisdictions resist the notion of growth limitations because of business or tax considerations or because of being economically depressed for one reason or another.

ISSUES FOR CONSIDERATION

(1) What is the difference between orderly and disorderly growth, and to what extent is such growth a State or local policy concern?

(2) How does Federal activity influence growth at the State and local levels?

(3) How would growth policy be related to local and State fiscal affairs and to the fiscal disparities among jurisdictions within metropolitan areas?

(4) Can or should a national growth policy address itself to local urban conditions such as central city decline, renewal, housing problems, poverty and the like?

(5) Is governance at the metropolitan level important in the formulation of implementation of growth policy? What kinds of environmental considerations can or ought to be delt with at the metropolitan level? What is the role of State governments in metropolitan area affairs?

(6) How can growth decisions at the State and local level be expected to impact resource use (including land use), and pollution generation? Is there a federal interest which is affected by these state and local decisions?

(7) How do state and local growth decisions influence land, marine, and fresh water wildlife habitats, and to what degree is there a Federal interest in the protection of these habitats? How can federal growth policy influence these state and local decisions?

Population

The growth of population is a key element in any consideration of national growth policy. What are the prospects for population in the United States and on a worldwide basis, and how can we expect population levels and rates of growth to be sensitive to public policy?

DISCUSSION

Rates of population increase differ among and within nations and have varying implications for nations and for subnational groups. The patterns of population change—changing levels, changing rates, changing age distributions, changing mortality rates and birth rates, changing patterns of geographic distribution—all have economic and social implications.

Population growth is effected by a variety of conditions, including the technological, demographic, sociological and the ideological. The degree to which it is sensitive to public policy is not clear.

In order to understand the implications of population growth for public policy decisions, it is important to clarify the relationships among population growth and other growth variables.

ISSUES FOR CONSIDERATION

(1) What are the implications of stabilized population growth for the health of business in the United States?

(2) Through what mechanisms is pollution a function of population?

(3) What is the theory of "demographic transition" and how does it apply to current world and U.S. conditions? What are the implications of demographic transition theory for the predictions contained in Limits and Blueprint?

(4) What are the growth policy implications of the findings and recommendations of the population commissions?

(5) What are the implications of population growth for land use and the pattern of urbanization in the United States?

Economic Growth

Environmentalists and those worried about the rate of resource consumption are calling for restraints on national and world economic growth. To what extent is national and world economic well-being dependent on growth and what are the implications of constrained and unconstrained growth in economic productivity?

DISCUSSION

Economic growth is seen as a key variable in the maintenance of standards of living, quality of life, and the like. It is seen as both a good and a bad variable, depending on the point of view of the evaluator. Since it is seen as a variable that determines our future in many regards, and since it is a widespread belief that economic growth is sensitive to changes in public policy, it is the source of political as well as technical controversy.

ISSUES FOR CONSIDERATION

(1) What is economic growth, how is it measured, and who benefits from it?
(2) What are the costs, both tangible and intangible, of economic growth?
(3) To what extent is national and world economic well-being determined by growth rates?
(4) Is economic growth sensitive to public policy? If so, how?
(5) What are the implications of constrained economic growth for the United States, for other developed countries and for underdeveloped countries? Is continued growth good for everyone? Is constrained growth good for everyone?
(6) To what extent does improved pollution control require the wealth derived from continued economic growth?
(7) To what extent does national security (military capacity) depend on economic growth?
(8) What is the role of agricultural and rural development in economic growth? What are the environmental problems united with such development?

Resource Scarcity

Resource scarcity is a key consideration in predictions of future world and national catastrophe. What is the outlook for resource availability and what are appropriate public policy responses to problems of scarcity?

DISCUSSION

The model builders whose work foretells disaster in the not-too-distant future have been criticized because of their treatment of resource scarcity. Although the finite nature of the earth is generally acknowledged, critics of the prophets assert that although resources will be in increasingly short supply, adjustment mechanisms by which society, adapts to changing conditions—the market and technological development—will lead to the availability of additional reserves, to substitution among resources and to reuse of many materials.

In spite of (or, more accurately, because of) the controversy over whether these adaptation mechanisms will be adequate to avoid catastrophe or at least to significantly delay it, the degree to which resource scarcity is a problem now and for future generations requires additional clarfiication.

ISSUES FOR CONSIDERATION

(1) Among resource experts how much variance exists on the degree to which both energy and nonenergy resource scarcity will lead to national and world crises?
(2) Will changing consumption patterns affect the onset of a resource crisis in any significant way?
(3) How do present governmental programs and policies affect the use and reuse of resources?
(4) What are the pollution effects of using increasingly lower-grade raw materials? What are the energy requirements for drawing upon these lower grade materials? Are we asking for a more severe thermal pollution problem by using such resources?

Environmental Pollution

Pollution can take many forms, and its effects can be both short and long-term. In many, perhaps most, respects, pollution involves the degradation of a commonly-held "good": someone else's environment. To what extent is it reasonable to develop aggregate policies for dealing with "pollution," and how are the costs and benefits of such an approach to be measured?

DISCUSSION

As a phenomenon, pollution has been with us for a very long time. It will be with us into the foreseeable future. The nations which are known as "developed" are beginning to spend considerable sums of money and amounts of time in an effort to cope with the problem: those known variously as "underdeveloped," "less developed," or "never to be developed" have been less so, although there is evidence that concern is rising here as well.

The "Limits to Growth," in its analysis of this variable, concentrated upon the long-term persistent pollutants, such as DDT and radioisotopes. It is also true that short-term pollutants can be highly toxic in their impact, although less globally significant at least on the first systems affected. Where do the real dangers exist, and how do we construct decisionmaking systems for dealing with these?

ISSUES FOR CONSIDERATION

(1) How do we assign priorities for the control of pollutants? By measurable dollar cost? By less measurable "social cost"? By ease of control? Or by source mixture of these?

(2) Who ought to make the decision to control or not control these pollutants?

(3) Who is or ought to be charged with monitoring the flow of pollutants on a global scale? How much budget should be assigned to this? How urgent is this duty.

(4) Has our dependence on this Earth's life support system ever been adequately described? Has the fragility of critical elements of that system been adequately assessed? Where do we find the biological limits to growth?

(5) At what point does a single pollutant—such as heat—become a significant concern?

(6) To what extent can we adjust to increasing levels of pollution? How long will it take and what increased levels of mortality must we accept in consequence?

(7) In what respects is the classical assumption of the "pollution threshold" still realistic?

Land Use

Economic growth and population growth have strong land use impacts. Public policy influences land use in many direct and indirect ways, and the pattern of land use, in turn, has implications for local, regional, and national economies, for the environment, for the use of resources, and for the welfare of future generations.

DISCUSSION

Many environmental, energy, and economic problems are related to how land is used—to the spatial distribution of economic activity and settlement clusters. To some extent, other social problems have land use dimensions as well. As economic output increases and population expands, the demand for land increases as well; and land use becomes a major element of national policy. This witnessed by the congressional attention given to land use in bills before the 92d Congress. The Senate, for example, passed a National Land Use Policy Act, and a Housing and Urban Development Act, with a land use element during 1972. Land use bills were also considered in the House as well.

ISSUES FOR CONSIDERATION

(1) How is land use related to economic growth, to environmental protection and to energy generation, distribution, and consumption?

(2) Do current patterns of urbanization threaten unnecessarily our land, marine, and fresh water wildlife?

(3) How can the competition for land between agricultural and nonagricultural uses be described? Is this an appropriate matter for public policy attention?

(4) How does current or recently proposed Federal policy influence or propose to influence land use? What are the growth implications? What are likely environmental impacts?

(5) What is the appropriate role for each of the various levels of Government in the federal system in land use planning and control? What are the predominant attitudes towards land use planning and control?

(6) What are the principal paradigms of land use and economic development (e.g., growth poles) and what are their policy implications?

(7) What mechanisms exist for implementing land use policy? What is the Federal interest in these mechanisms?

Market Mechanisms for Adjustment to Changing Patterns of Scarcity

How can the mechanisms of the marketplace help society adjust to declining available supplies of resources, stimulate substitution among resources, and encourage the development and application of technologies to problems of resource scarcities and of pollution control?

DISCUSSION

The critics of "Limits" and similar documents have pointed out that one of the major weaknesses of the model is that it does not reflect the existence of adjustment mechanisms which would prevent or at least mitigate or postpone the crisis which is predicted. The market is part of this set of adjustment mechanisms, since the use of scarce resources in production is a function of price, which fluctuates in the marketplace as supply and demand interact. This mechanism will have a number of effects. The first is that as price increases, new reserves of resources can become available. The second is that as price increases, substitution among various resources will occur. The third is that for many products, as price increases, the growth of aggregate demand will be restrained Other effects could be pointed out. These arguments do not allow us to cast aside or to ignore the finite nature of the Earth, but they are considerations that were not included in the formulation of the "Limits" model and they may suggest that the future problem will not be of the catastrophic nature the model builders predict.

ISSUES FOR CONSIDERATION

(1) To what extent can these market mechanisms be relied upon to allocate resources and to buffer future generations from the rapid decline depicted by limits and blueprint?

(2) What are the limitations of the marketplace? What additional incentives and restraints would be required to supplement the price system in order to influence the use and reuse of resources and to influence the generation of pollutants?

(3) How can the marketplace influence research and development efforts aimed at expanding the usability and reusability of resources and at pollution control?

(4) What would be the impact of price determination by cartels on the ability of the market to adjust consumption as physical limits are approached.

Technology as an Adjustment Mechanism

To what extent can we rely on technological advances to ease the problems of scarcity and pollution and to buffer world economic and social systems against rapid decline when growth limits are approached or reached?

What are the implications of technologic differentials among nations?

DISCUSSION

The critics of the movement to limit growth assert that technology is growing expotentially, just as are population and economic production, and that many of the dangers of growth—those associated with resource exhaustion and environmental pollution—will be mitigated by continued technological development. Others assert that this is not the case, that there are "certain kinds of pollution that cannot be avoided, short of the most far-reaching changes in our industrial technology, and one kind (thermal pollution) that cannot be avoided by any known or imagined technology." (Kaysen) Defenders of the limits notion point to the basic finite nature of the earth and to the inevitability of exhaustion in spite of technological advances that allow further exploitation of resources and reuse of resources.

ISSUES FOR CONSIDERATION

(1) What is the state of the art and the foreseeable development of technologies for expanding our ability to draw upon resource reserves?

(2) To what extent can technological methods increase food supplies?

(3) What are the costs of these technologies and how can costs be expected to change over the coming decades?

(4) What are the pollution propensities of these technologies?

(5) What is the state of the art and the foreseeable development of technologies for avoiding or removing pollutants? What are the costs?

(6) How will new technologies affect energy needs and capacities to produce that energy? How can technology affect the polluting outputs of energy production? Is the thermal pollution problem as serious as some would have us believe?

(7) To what extent are new technologies—or existing technologies—applicable to developing countries, and can their need for growth to meet immediate problems be helped by these technologies? Can they bear the costs of these technologies? Can technology help to alter the distribution of wealth and income among nations?

(8) To what extent must there be continued investment in research and development to realize future technological potentials? Do current Research and Development priorities reflect future needs with regard to resource utilization and pollution control?

Executive Branch Treatment of Growth Issues

How is the executive branch currently organized to deal with growth issues, and what actions has the administration taken toward the development of a national growth policy?

DISCUSSION

In 1970 the Congress required that a national urban growth policy be developed and that a unit of the President's Domestic Council submit a report on national urban growth to the Congress in every even-numbered year beginning with 1972. The President's 1972 report echoed the widespread conviction that urban growth is a special aspect of more broadly defined growth. Other aspects of growth are properly the subject of energy policy, population policy, land-use policy, materials policy, rural development policy, and the like—just as is urban growth policy. A national growth policy can be seen as a composite of these narrowly defined policies or perhaps as the umbrella under which they are gathered and interrelated.

The executive branch must necessarily play an important role in the development or a national growth policy, if one is to be developed, and it has in fact taken steps to develop an improved understanding of growth policy issues—in spite of the impressions to be gained from the 1972 growth report. The President's domestic adviser John D. Ehrlichman issued a memorandum to a number of executive agencies asking them to respond by July 30, 1972, to an extensive list of questions regarding the formulation of national growth policy.

The nature of Executive efforts toward the formulation of a national growth policy—or toward the decision of whether or not to formulate such a policy—may be of interest to the committee in order to assess the degree to which growth policy may affect the matters over which the committee has jurisdiction.

ISSUES FOR CONSIDERATION

(1) How is the pattern of national growth being affected by the management of existing Federal programs, especially with regard to energy, population, land use, urban and metropolitan development, materials, air and water resources?

(2) How is the executive branch organized to deal with growth issues?

(3) From a substantive point of view, what decisions have been made with regard to national growth policy? How were the decisions related to information provided in response to the Ehrlichman memorandum?

(4) How can the Nation's present growth policy be characterized?

(5) From the administration's point of view, where is growth sensitive to Federal, State, or local public policy?

Mr. Dingell. The Chair again does reiterate my personal thanks to each of you, the thanks of the committee and the appreciation for your invaluable assistance to us today.

If there is no further business to come before the committee, the committee will stand adjourned until the call of the Chair.

[Whereupon, at 4:05 p.m., the subcommittee adjourned to reconvene subject to the call of the Chair.]

APPENDIX

MAY 21, 1973.

To: Hon. John D. Dingell, Chairman, Subcommittee on Fisheries and Wildlife Conservation and the Environment, Committee on Merchant Marine and Fisheries.

From: Government and General Research Division; Charles W. Harris, Division Chief—The Library of Congress, Congressional Research Service.

Subject: Appendix material for May 1 hearing on growth. Research by Clay H. Wellborn.

In response to your request we are enclosing the reader on growth to be appended to the hearing record from your May 1 hearing on growth and the environment. We have also prepared a brief introduction to accompany the documents.

If we can be of further assistance in this matter, please do not hesitate to call.

Selected Readings on National Growth and the Environment

I. CATALYSTS OF CONTROVERSY

1. *The Limits to Growth*, by Donella H. Meadows, Dennis L. Meadows, Jørgen Randers, and William W. Behrens III.

Commentary

"Can the World Survive Economic Growth" by J. Church (Time, Aug. 14, 1972).

"The Computer that Printed Out Wolf," by Carl Kaysen (Foreign Affairs, Summer 1972).

"Growth and its Enemies," by Rudolf Klein (Commentary, June 1972).

"Predicament of Mankind," by Allen Kneese and Ronald Ridker (Washington Post, Mar 2, 1972).

"Limits to Growth, A Critique," by Mahbub ul Haq (Finance and Development).

Review of *Limits to Growth*, by E. J. Mishan (New Scientist, May 1972).

"Growth and Survival," by Robert L. Heilbroner (Foreign Affairs, October 1972).

Rejoinder

"Limits to Growth in Perspective," by Aurelio Peccei and Manfred Siebker.

"A Summary of Limits to Growth—Its Critics and Its Challenge," by Donella H. and Dennis L. Meadows.

2. "A Blueprint for Survival," by Edward Goldsmith, Robert Allen, Michael Allaby, John Davoll, and Sam Lawrence (The Ecologist, January 1972).[1]

Commentary

Letters to the editor of The Ecologist from Sir Julian Huxley (March 1972); Prof. C. H. Waddington (March 1972); Sir Geoffrey Vickers (March 1972); Sir Eric Ashby (April 1972); and The Rt. Rev. Hugh Montefiore (April 1972).

"A Word of Warning," by Samuel Mines (Washington Post, Dec. 20, 1972).

II. GENERAL COMMENTARY ON THE PROBLEMS OF GROWTH

1. "How to Live with Economic Growth," by Henry C. Wallich (Fortune, October 1972).

[1] Now published separately as a book.

2. "Coming to Terms with Growth and the Environment," by Walter W. Heller (Energy, Economic Growth and the Environment, Sam H. Schurr, editor).
3. "The Doomsday Syndrome," by John Maddox (Saturday Review, Oct. 21, 1972).
4. "Avoiding a Limit to Growth," by W. Donham Crawford (American Power Conference, Apr. 18, 1972).
5. "The Ecological Effects of Growth," by George M. Woodwell (Congressional Record, Apr. 3, 1973).
6. "A Model for a Steady-State Economy," by Herman E. Daly (October 1972).

III. BACKGROUND DOCUMENTS

1. *Rapid Population Growth*, prepared by a study committee of the Foreign Secretary, National Academy of Sciences (1971).
2. *Population and the American Future*, report of the President's Commission on Population and the American Future (Mar. 27, 1972).
3. *Resources and Man*, prepared by the Committee on Resources and Man, National Academy of Sciences-National Research Council (1969).
4. Toward a National Materials Policy. Basic Data and Issues, National Commission on Materials Policy (April 1972).
5. Elements of a National Materials Policy, report of the National Materials Advisory Board, National Research Council-National Academy of Engineering (August 1972).
6. *Only One Earth*, by Barbara Ward and Rene Dubos (1972).

IV. NATIONAL GROWTH POLICY IN THE UNITED STATES

1. Report on National Growth 1972, President's first biennial report on national growth as required by the Housing and Urban Development Act of 1970.

Commentary

"Missing: One Policy," (New York Times, Mar. 29, 1972).

"Urban Growth" (Washington Post, Apr. 8, 1972).

"Comments on National Growth," by Jay Forrester (U.S. House of Representatives, Committee on Banking and Currency, Subcommittee on Housing. Hearings on National Growth Policy, June 6, 7, 1972, pt. 2).

2. Land Use and Urban Growth, summary of the report of the Task Force on Land Use and Urban Growth of the Citizens' Advisory Committee on Environmental Quality.
3. White House memorandum on National Growth Policy, dated May 31, 1972.

Selected Readings on National Growth and the Environment

The material presented here for the reference of the committee is divided into four sections.

Section I consists of excerpts from and commentary on two documents that have generated extensive controversy over the desirability and probable long-run outcomes of continued growth in population and economic productivity. The controversial documents are entitled "The Limits to Growth" and "Blueprint for Survival."

Section II is a selection of articles commenting generally on aspects of a growth-oriented versus a steady-state society.

Section III assembles excerpts from six documents that have played important roles in presenting current thinking on population, resources, and the environment.

Section IV is a collection of documents reflecting the state of development of national urban growth policy in the United States. Included are excerpts from the President's Report on Growth 1972, which was required by the Housing and Urban Development Act of 1970. A brief selection of editorial and scholarly comment is included.

Current executive branch thinking on the subject of growth is indicated by a White House memorandum on the subject, and private sector thinking is reflected by the summary of the report of the Task Force on Land Use and Urban Growth of the Citizen's Advisory Committee on Environmental Quality.

Overview of the Documents

The documents collected here suggest a consensus only on two matters related to growth. First, there is agreement that the earth's resources are not infinite. Second, there is a consensus that there are no additional benefits to be derived from additional growth in population. Beyond these two points of agreement, consensus is hard to find. The call for transition from a growth-oriented society to a steady-state society is countered by the call for continued growth to provide the resources needed for environmental protection and for maintaining or improving standards of living in both developed and developing societies. Predictions of disaster on a worldwide scale are challenged by those who assert that the predictions are based on insufficient evidence, on faulty methods, and on unsubstantiated assumptions. None of the participants in the controversy deny the need for thoughtful stewardship of the earth's resources or for careful husbandry of the planet's fragile biosphere, but there is no consensus on what thoughtful stewardship and careful husbandry should consist of. Indeed, we are presented with a harsh dilemma, a dilemma for which these documents offer no solution. We are presented on the one hand with the prospect of exhaustion of our resources and of ecological disaster if we do not convert from a growth-oriented society to a steady-state society. On the other hand we are presented with the necessity of economic growth if the developing nations are to escape evermore deepening poverty and developed nations are to maintain their standards of living. We are also told that the social strains associated with transition to a steady-state society as well as those that will be created by continuing the growth orientation may be more than we will be able to manage.

If there is room for limited optimism given these extremes it is in the general agreement that limitation of population increases may delay catastrophe. But population control is not easy to achieve on a worldwide basis, and in itself it is not a panacea because of increasing per capita demand for resources.

What these documents achieve whether or not they forecast catastrophe is to call attention of the policymaker to the complex and difficult problems we as dependents of the Earth are coming to find ourselves with. They plead with us to reassess our patterns of consumption, to take action to improve our understanding of the world we live in, and to address ourselves to its capacity to sustain us.

Section I: Catalysts of Controversy and Their Critics

The document that has been the most highly publicized and that has therefore played the most important role in generating controversy over the question of growth is the Club of Rome's publication *The Limits of Growth*, prepared under the direction of Prof. Dennis Meadows.

Limits concludes that "If present growth trends in world population industrialization, pollution, food production, and resource depletion continue unchanged, the limits to growth on this planet will be reached sometime within the hundred years. The most probable result will be a rather sudden and uncontrolled decline in both population and industrial capacity."

Professor Meadows amplified this prediction in his testimony before the subcommittee by noting that the limits to growth are already making themselves felt in such things as increasing world pollution levels. Dr. Lester Brown made a similar suggestion in his testimony on the world food situation.

But Limits goes on to say that if the present trends are changed soon, it may be possible to sustain ecological and economic stability rather far into the future.

The excepts from Limits selected to be included in this collection describe the nature of current expotential growth trends, identify some of the likely limits to expotential growth, and characterize the state of global equilibrium (zero growth of population and industrial activity) that the authors believe must be achieved if our ecological and economic well-being are to be sustained at acceptable levels.

"Blueprint for Survival", published in the British journal *The Ecologist*, makes a similar case, but it goes further to suggest a strategy for the transition from current growth patterns to more sustainable patterns. "Blueprint" includes in its proposed strategy a series of changes in the sociopolitical structure that would be required to enforce the restraint needed to effect the transition while preserving individual liberty. (Other documents in this collection also discuss the problems of "macro" constraints on the economic system and the need to avoid "micro" constraints that would severely abridge individual liberty.)

A selection of the critical responses to these two documents follows the excerpts from each of them. Although the responses to both of the documents have been similar in content, responses to Limits have been especially extensive and vigorous. Carl Kaysen, for example, begins his critique of Limits by pointing out that it has "generated many times its own weight in enthusiastic encomia and equally strong condemnations."

In a Time magazine article, George J. Church briefly highlights the arguments presented in Limits and points to the criticisms which it generated almost immediately after its publication. He urges that the underlying thrust of Limits not be disregarded because of whatever technical flaws it may have.

Carl Kaysen, however, asserts that Limits is somewhat of a false alarm, that "the authors' analysis is gravely deficient and many of their strongest and most striking conclusions [are] unwarranted." Nevertheless, Kaysen joins others in acknowledging that Limits draws attention to important and difficult problems.

Rudolf Klein begins his critique of Limits by comparing it to a long series of Western prophets whose predictions of catastrophe were not fulfilled. He urges us to maintain a balanced view of the whole range of complex problems which face mankind, only one of which is growth.

Kneese and Ridker find that Limits presents an interesting discussion of population, pollution, and resource depletion, but one that is not superior to many of the others which are available. They join other critics in pointing out the weakness of the model used by the authors, finding it an "interesting framework "for resource and environmental management research, but not in itself" a helpful near-term tool for strengthening and deepening our understanding of man's predicament and what to do about it."

Looking at Limits from the perspective of a World Bank economist, Mahub ul Haq finds that it reflects a complacency about world "social and political problems which its own prescriptions would only exacerbate." He concludes that "industrial countries may be able to accept a target of zero growth (in economic production) as a disagreeable, yet perhaps morally bracing regime for their own citizens. For the developing world, however, zero growth offers only a prospect of despair * * *."

Heilbroner, commenting on both Limits and "Blueprint", remarks that it is not growth per se that is the problem, but the pollution that growth generates. He is therefore a bit more optimistic about the practicability of technological solutions to many of the pollution problems growth creates. He joins the authors of Limits and "Blueprint" in their belief that something approaching a steady-state society is essential, but he is not at all sanguine about our capacities to cope with the social problems the transition would cause.

Ezra Mishan is less interested in the weaknesses of the model the author of Limits base their analysis upon than he is in reactions to Limits. He correctly predicts that economists will almost surely dislike Limits, and he predicts that they will almost surely set to work on similar models in order to make additional contributions to their utility.

Criticisms of "Blueprint" are quite similar to those of Limits, as evidenced by the short selection of letters from noted British scholars to the editor of The Ecologist.

REJOINDERS

The discussion of Limits concludes with rejoinders from both the Meadows team and from Aurelio Peccei, leader of the Club of Rome, who answer their critics on a point-by-point basis.

SECTION II: GENERAL COMMENTARY ON THE PROBLEMS OF GROWTH

Henry Wallich, a proponent of economic growth, suggests ways of benefiting from growth while avoiding catastrophe and controlling some of the undesirable side effects of growth. He sees the price system as a powerful tool in the effort to avoid the hazards of growth.

Walter Heller identifies points of agreement and disagreement between economists and environmentalists, pointing out that economics regards the structure of growth rather than the fact of growth as the root of environmental evil. Heller joins Heilbroner in doubting our capacity to overcome the social and political problems that transition to a steady-state society would provide.

John Maddox, editor of the British scientific journal *Nature*, accuses environmentalists of using international overdramatization and of diverting public at-

tention away from the real ecological issues and from existing currently available solutions to real ecological problems.

To supplement the discussion, the point of view of an industry spokesman, W. Donham Crawford of the American Power Conference, is included as is the point of view of environmentalist George M. Woodwell.

Section II closes with a paper by Herman Daly who argues for the achievement of a steady-state society by (1) establishing macro controls, and (2) avoiding micro controls that would hinder individual freedoms.

SECTION III. BACKGROUND DOCUMENTS

Two documents in this section examine the role of population increase both worldwide and within the United States. Included are excerpts from "Rapid Population Growth," prepared by a study committee of the Office of the Foreign Secretary, National Academy of Sciences, and the report of the President's Commission on Population and the American Future. Both of these documents call for public efforts to constrain population increase.

Three additional documents consider growth from a resource management point of view: *Resources and Man*, prepared by the Committee on Resources and Man, National Academy of Sciences-National Research Council; *Towards a National Materials Policy—Basic Data and Issues*, prepared by the National Commission on Materials Policy; and *Elements of a National Materials Policy*, the report of the National Materials Advisory Board, National Research Council-National Academies of Science and Engineering.

Finally, *Only One Earth* offers a review of man's role in the management of the biosphere.

SECTION IV: NATIONAL GROWTH POLICY IN THE UNITED STATES

The Housing and Urban Development Act of 1970 required the President to submit to the Congress every 2 years a report on urban growth in the United States as part of the process to develop a national urban growth policy. Excerpts from the first report are presented here because urbanization is a vital part of growth and because the report indicated an executive decision by the present administration not to address itself to the development of a national urban growth policy at the time of the report. Since that time a White House memorandum, included here, was circulated to agency heads to generate information and recommendations on the desirability and feasibility of formulating growth policy. The outcome of that request for information and recommendations is not known.

At the time the President's report was submitted to the Congress, there was widespread disappointment in its lack of policy content. This disappointment is reflected in the comments that follow the excerpt from the report itself.

That there continues to exist an active national concern for the development of both land use and urban growth policy is witnessed by the existence of a task force on land use and urban growth within the Citizens' Advisory Committee on Environmental Quality. A summary of their forthcoming report is included as the last item in this collection of documents.

EFFICACY OF PRICE AND TECHNOLOGY IN ADJUSTMENT MECHANISMS

Review of the material presented here will show that fundamental disagreement exists as to whether the price system and technological advance will allow us to adjust adequately to increasingly scarce resources by altering aggregate demand and by allowing substitution among factors of production. This disagreement is important because what one believes about the efficacy of these adjustment mechanisms will influence one's evaluation of both the prophecies of catastrophe and the criticisms of such prophecies. The documents assembled here do not in any way resolve the disagreement; they merely demonstrate its existence and its centrality in the debate.

A POTOMAC ASSOCIATES BOOK

THE LIMITS TO growth

A REPORT FOR
THE CLUB OF ROME'S PROJECT ON
THE PREDICAMENT OF MANKIND

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Universe Books
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FOREWORD

IN APRIL 1968, a group of thirty individuals from ten countries—scientists, educators, economists, humanists, industrialists, and national and international civil servants—gathered in the Accademia dei Lincei in Rome. They met at the instigation of Dr. Aurelio Peccei, an Italian industrial manager, economist, and man of vision, to discuss a subject of staggering scope—the present and future predicament of man.

THE CLUB OF ROME

Out of this meeting grew The Club of Rome, an informal organization that has been aptly described as an "invisible college." Its purposes are to foster understanding of the varied but interdependent components—economic, political, natural, and social—that make up the global system in which we all live; to bring that new understanding to the attention of policy-makers and the public worldwide; and in this way to promote new policy initiatives and action.

The Club of Rome remains an informal international association, with a membership that has now grown to approximately seventy persons of twenty-five nationalities. None of its members holds public office, nor does the group seek to express any single ideological, political, or national point of view. All are united, however, by their overriding conviction that the major problems facing mankind are of such complexity and are so interrelated that traditional institutions and policies are

no longer able to cope with them, nor even to come to grips with their full content.

The members of The Club of Rome have backgrounds as varied as their nationalities. Dr. Peccei, still the prime moving force within the group, is affiliated with Fiat and Olivetti and manages a consulting firm for economic and engineering development, Italconsult, one of the largest of its kind in Europe. Other leaders of The Club of Rome include: Hugo Thiemann, head of the Battelle Institute in Geneva; Alexander King, scientific director of the Organization for Economic Cooperation and Development; Saburo Okita, head of the Japan Economic Research Center in Tokyo; Eduard Pestel of the Technical University of Hannover, Germany; and Carroll Wilson of the Massachusetts Institute of Technology. Although membership in The Club of Rome is limited, and will not exceed one hundred, it is being expanded to include representatives of an ever greater variety of cultures, nationalities, and value systems.

THE PROJECT ON THE PREDICAMENT OF MANKIND

A series of early meetings of The Club of Rome culminated in the decision to initiate a remarkably ambitious undertaking —the Project on the Predicament of Mankind.

The intent of the project is to examine the complex of problems troubling men of all nations: poverty in the midst of plenty; degradation of the environment; loss of faith in institutions; uncontrolled urban spread; insecurity of employment; alienation of youth; rejection of traditional values; and inflation and other monetary and economic disruptions. These seemingly divergent parts of the "world problematique," as The Club of Rome calls it, have three characteristics in com-

mon: they occur to some degree in all societies; they contain technical, social, economic, and political elements; and, most important of all, they interact.

It is the predicament of mankind that man can perceive the problematique, yet, despite his considerable knowledge and skills, he does not understand the origins, significance, and interrelationships of its many components and thus is unable to devise effective responses. This failure occurs in large part because we continue to examine single items in the problematique without understanding that the whole is more than the sum of its parts, that change in one element means change in the others.

Phase One of the Project on the Predicament of Mankind took definite shape at meetings held in the summer of 1970 in Bern, Switzerland, and Cambridge, Massachusetts. At a two-week conference in Cambridge, Professor Jay Forrester of the Massachusetts Institute of Technology (MIT) presented a global model that permitted clear identification of many specific components of the problematique and suggested a technique for analyzing the behavior and relationships of the most important of those components. This presentation led to initiation of Phase One at MIT, where the pioneering work of Professor Forrester and others in the field of System Dynamics had created a body of expertise uniquely suited to the research demands.

The Phase One study was conducted by an international team, under the direction of Professor Dennis Meadows, with financial support from the Volkswagen Foundation. The team examined the five basic factors that determine, and therefore, ultimately limit, growth on this planet—population, agricultural production, natural resources, industrial production,

and pollution. The research has now been completed. This book is the first account of the findings published for general readership.

A GLOBAL CHALLENGE

It is with genuine pride and pleasure that Potomac Associates joins with The Club of Rome and the MIT research team in the publication of *The Limits to Growth.*

We, like The Club of Rome, are a young organization, and we believe the Club's goals are very close to our own. Our purpose is to bring new ideas, new analyses, and new approaches to persistent problems—both national and international—to the attention of all those who care about and help determine the quality and direction of our life. We are delighted therefore to be able to make this bold and impressive work available through our book program.

We hope that *The Limits to Growth* will command critical attention and spark debate in all societies. We hope that it will encourage each reader to think through the consequences of continuing to equate growth with progress. And we hope that it will lead thoughtful men and women in all fields of endeavor to consider the need for concerted action now if we are to preserve the habitability of this planet for ourselves and our children.

William Watts, *President*
POTOMAC ASSOCIATES

INTRODUCTION

I do not wish to seem overdramatic, but I can only conclude from the information that is available to me as Secretary-General, that the Members of the United Nations have perhaps ten years left in which to subordinate their ancient quarrels and launch a global partnership to curb the arms race, to improve the human environment, to defuse the population explosion, and to supply the required momentum to development efforts. If such a global partnership is not forged within the next decade, then I very much fear that the problems I have mentioned will have reached such staggering proportions that they will be beyond our capacity to control.

U THANT, 1969

The problems U Thant mentions—the arms race, environmental deterioration, the population explosion, and economic stagnation—are often cited as the central, long-term problems of modern man. Many people believe that the future course of human society, perhaps even the survival of human society, depends on the speed and effectiveness with which the world responds to these issues. And yet only a small fraction of the world's population is actively concerned with understanding these problems or seeking their solutions.

HUMAN PERSPECTIVES

Every person in the world faces a series of pressures and problems that require his attention and action. These problems

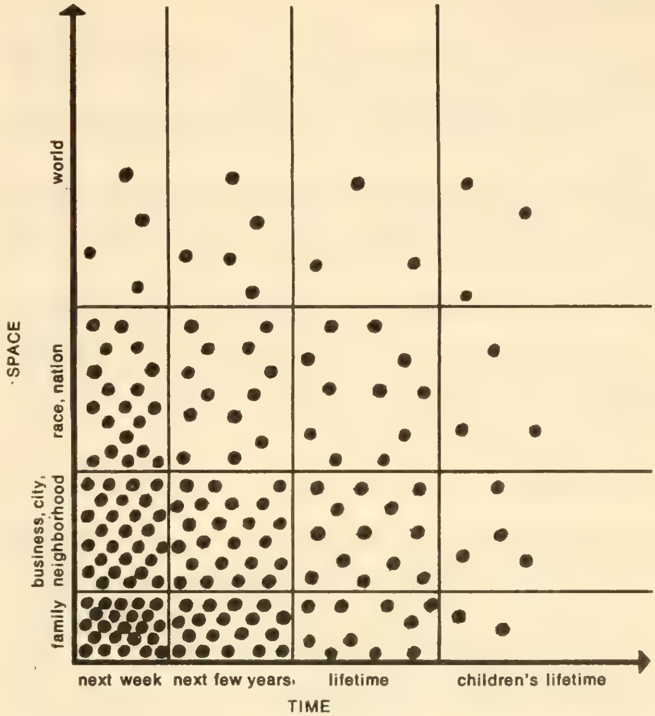
affect him at many different levels. He may spend much of his time trying to find tomorrow's food for himself and his family. He may be concerned about personal power or the power of the nation in which he lives. He may worry about a world war during his lifetime, or a war next week with a rival clan in his neighborhood.

These very different levels of human concern can be represented on a graph like that in figure 1. The graph has two dimensions, space and time. Every human concern can be located at some point on the graph, depending on how much geographical space it includes and how far it extends in time. Most people's worries are concentrated in the lower left-hand corner of the graph. Life for these people is difficult, and they must devote nearly all of their efforts to providing for themselves and their families, day by day. Other people think about and act on problems farther out on the space or time axes. The pressures they perceive involve not only themselves, but the community with which they identify. The actions they take extend not only days, but weeks or years into the future.

A person's time and space perspectives depend on his culture, his past experience, and the immediacy of the problems confronting him on each level. Most people must have successfully solved the problems in a smaller area before they move their concerns to a larger one. In general the larger the space and the longer the time associated with a problem, the smaller the number of people who are actually concerned with its solution.

There can be disappointments and dangers in limiting one's view to an area that is too small. There are many examples of a person striving with all his might to solve some immediate, local problem, only to find his efforts defeated by events occurring in a larger context. A farmer's carefully maintained

Figure 1 HUMAN PERSPECTIVES



Although the perspectives of the world's people vary in space and in time, every human concern falls somewhere on the space-time graph. The majority of the world's people are concerned with matters that affect only family or friends over a short period of time. Others look farther ahead in time or over a larger area—a city or a nation. Only a very few people have a global perspective that extends far into the future.

fields can be destroyed by an international war. Local officials' plans can be overturned by a national policy. A country's economic development can be thwarted by a lack of world demand for its products. Indeed there is increasing concern today that most personal and national objectives may ultimately be frustrated by long-term, global trends such as those mentioned by U Thant.

Are the implications of these global trends actually so threatening that their resolution should take precedence over local, short-term concerns?

Is it true, as U Thant suggested, that there remains less than a decade to bring these trends under control?

If they are not brought under control, what will the consequences be?

What methods does mankind have for solving global problems, and what will be the results and the costs of employing each of them?

These are the questions that we have been investigating in the first phase of The Club of Rome's Project on the Predicament of Mankind. Our concerns thus fall in the upper right-hand corner of the space-time graph.

PROBLEMS AND MODELS

Every person approaches his problems, wherever they occur on the space-time graph, with the help of models. A model is simply an ordered set of assumptions about a complex system. It is an attempt to understand some aspect of the infinitely varied world by selecting from perceptions and past experience a set of general observations applicable to the problem at hand. A farmer uses a mental model of his land, his assets, market prospects, and past weather conditions to decide which crops to plant each year. A surveyor constructs a physical model—a map—to help in planning a road. An economist uses mathematical models to understand and predict the flow of international trade.

Decision-makers at every level unconsciously use mental models to choose among policies that will shape our future world. These mental models are, of necessity, very simple when

compared with the reality from which they are abstracted. The human brain, remarkable as it is, can only keep track of a limited number of the complicated, simultaneous interactions that determine the nature of the real world.

We, too, have used a model. Ours is a formal, written model of the world.* It constitutes a preliminary attempt to improve our mental models of long-term, global problems by combining the large amount of information that is already in human minds and in written records with the new information-processing tools that mankind's increasing knowledge has produced—the scientific method, systems analysis, and the modern computer.

Our world model was built specifically to investigate five major trends of global concern—accelerating industrialization, rapid population growth, widespread malnutrition, depletion of nonrenewable resources, and a deteriorating environment. These trends are all interconnected in many ways, and their development is measured in decades or centuries, rather than in months or years. With the model we are seeking to understand the causes of these trends, their interrelationships, and their implications as much as one hundred years in the future.

The model we have constructed is, like every other model, imperfect, oversimplified, and unfinished. We are well aware of its shortcomings, but we believe that it is the most useful model now available for dealing with problems far out on the space-time graph. To our knowledge it is the only formal model in existence that is truly global in scope, that has a

* The prototype model on which we have based our work was designed by Professor Jay W. Forrester of the Massachusetts Institute of Technology. A description of that model has been published in his book *World Dynamics* (Cambridge, Mass.: Wright-Allen Press, 1971).

time horizon longer than thirty years, and that includes important variables such as population, food production, and pollution, not as independent entities, but as dynamically interacting elements, as they are in the real world.

Since ours is a formal, or mathematical, model it also has two important advantages over mental models. First, every assumption we make is written in a precise form so that it is open to inspection and criticism by all. Second, after the assumptions have been scrutinized, discussed, and revised to agree with our best current knowledge, their implications for the future behavior of the world system can be traced without error by a computer, no matter how complicated they become.

We feel that the advantages listed above make this model unique among all mathematical and mental world models available to us today. But there is no reason to be satisfied with it in its present form. We intend to alter, expand, and improve it as our own knowledge and the world data base gradually improve.

In spite of the preliminary state of our work, we believe it is important to publish the model and our findings now. Decisions are being made every day, in every part of the world, that will affect the physical, economic, and social conditions of the world system for decades to come. These decisions cannot wait for perfect models and total understanding. They will be made on the basis of some model, mental or written, in any case. We feel that the model described here is already sufficiently developed to be of some use to decision-makers. Furthermore, the basic behavior modes we have already observed in this model appear to be so fundamental and general that we do not expect our broad conclusions to be substantially altered by further revisions.

It is not the purpose of this book to give a complete, scientific description of all the data and mathematical equations included in the world model. Such a description can be found in the final technical report of our project. Rather, in *The Limits to Growth* we summarize the main features of the model and our findings in a brief, nontechnical way. The emphasis is meant to be not on the equations or the intricacies of the model, but on what it tells us about the world. We have used a computer as a tool to aid our own understanding of the causes and consequences of the accelerating trends that characterize the modern world, but familiarity with computers is by no means necessary to comprehend or to discuss our conclusions. The implications of those accelerating trends raise issues that go far beyond the proper domain of a purely scientific document. They must be debated by a wider community than that of scientists alone. Our purpose here is to open that debate.

The following conclusions have emerged from our work so far. We are by no means the first group to have stated them. For the past several decades, people who have looked at the world with a global, long-term perspective have reached similar conclusions. Nevertheless, the vast majority of policy-makers seems to be actively pursuing goals that are inconsistent with these results.

Our conclusions are:

1. If the present growth trends in world population, industrialization, pollution, food production, and resource depletion continue unchanged, the limits to growth on this planet will be reached sometime within the next one hundred years. The most probable result will be a rather sudden and uncontrollable decline in both population and industrial capacity.

2. It is possible to alter these growth trends and to establish a condition of ecological and economic stability that is sustainable far into the future. The state of global equilibrium could be designed so that the basic material needs of each person on earth are satisfied and each person has an equal opportunity to realize his individual human potential.

3. If the world's people decide to strive for this second outcome rather than the first, the sooner they begin working to attain it, the greater will be their chances of success.

These conclusions are so far-reaching and raise so many questions for further study that we are quite frankly overwhelmed by the enormity of the job that must be done. We hope that this book will serve to interest other people, in many fields of study and in many countries of the world, to raise the space and time horizons of their concerns and to join us in understanding and preparing for a period of great transition—the transition from growth to global equilibrium.

CHAPTER I

THE NATURE OF EXPONENTIAL GROWTH

People at present think that five sons are not too many and each son has five sons also, and before the death of the grandfather there are already 25 descendants. Therefore people are more and wealth is less; they work hard and receive little.

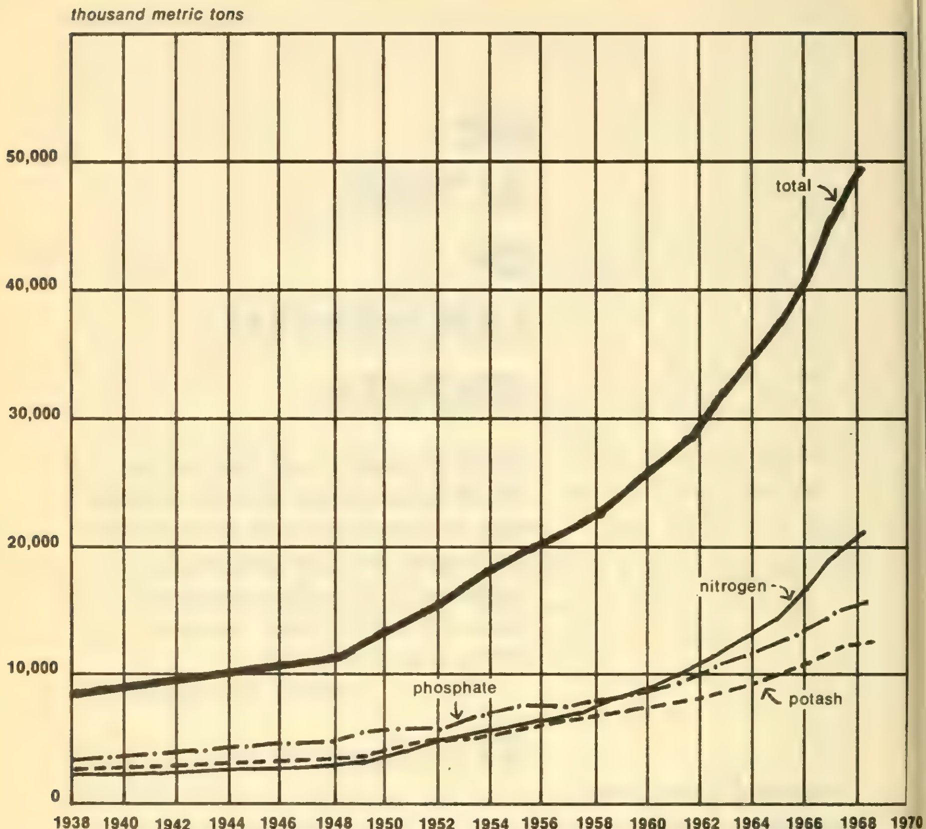
HAN FEI-TZU, ca. 500 B.C.

All five elements basic to the study reported here—population, food production, industrialization, pollution, and consumption of nonrenewable natural resources—are increasing. The amount of their increase each year follows a pattern that mathematicians call exponential growth. Nearly all of mankind's current activities, from use of fertilizer to expansion of cities, can be represented by exponential growth curves (see figures 2 and 3). Since much of this book deals with the causes and implications of exponential growth curves, it is important to begin with an understanding of their general characteristics.

THE MATHEMATICS OF EXPONENTIAL GROWTH

Most people are accustomed to thinking of growth as a *linear* process. A quantity is growing linearly when it increases by a

Figure 2 WORLD FERTILIZER CONSUMPTION



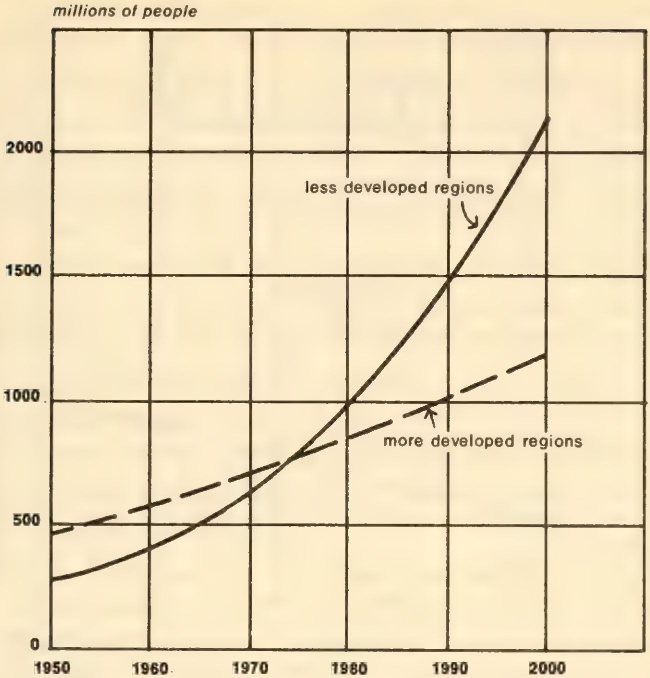
World fertilizer consumption is increasing exponentially, with a doubling time of about 10 years. Total use is now five times greater than it was during World War II.

NOTE: Figures do not include the USSR or the People's Republic of China.

SOURCES: UN Department of Economic and Social Affairs, *Statistical Yearbook 1955*, *Statistical Yearbook 1960*, and *Statistical Yearbook 1970* (New York: United Nations, 1956, 1961, and 1971).

constant amount in a constant time period. For example, a child who becomes one inch taller each year is growing linearly. If a miser hides $10 each year under his mattress, his

Figure 3 WORLD URBAN POPULATION



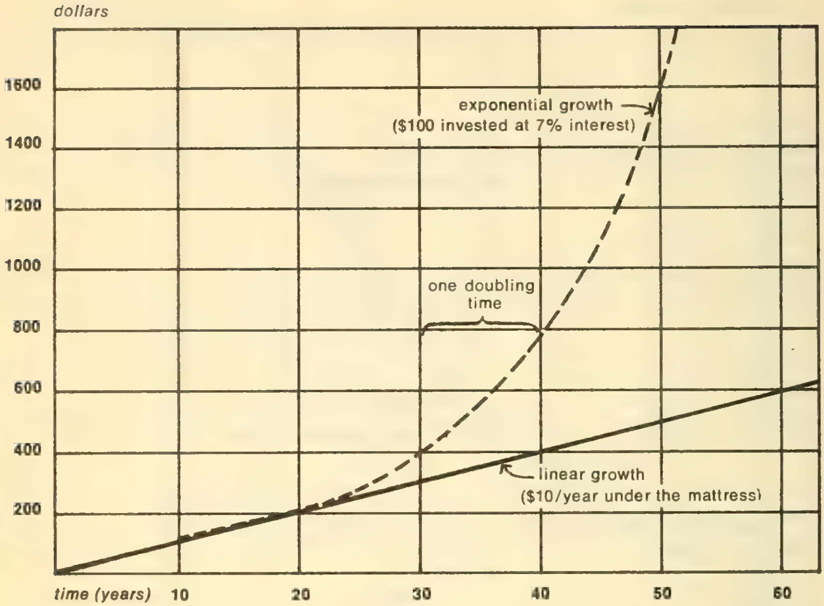
Total urban population is expected to increase exponentially in the less developed regions of the world, but almost linearly in the more developed regions. Present average doubling time for city populations in less developed regions is 15 years.

SOURCE: UN Department of Economic and Social Affairs, *The World Population Situation in 1970* (New York: United Nations, 1971).

horde of money is also increasing in a linear way. The amount of increase each year is obviously not affected by the size of the child nor the amount of money already under the mattress.

A quantity exhibits *exponential* growth when it increases by a constant percentage of the whole in a constant time period. A colony of yeast cells in which each cell divides into two cells every 10 minutes is growing exponentially. For each single cell, after 10 minutes there will be two cells, an increase

Figure 4 THE GROWTH OF SAVINGS



If a miser hides $10 each year under his mattress, his savings will grow linearly, as shown by the lower curve. If, after 10 years, he invests his $100 at 7 percent interest, that $100 will grow exponentially, with a doubling time of 10 years.

of 100 percent. After the next 10 minutes there will be four cells, then eight, then sixteen. If a miser takes $100 from his mattress and invests it at 7 percent (so that the total amount accumulated increases by 7 percent each year), the invested money will grow much faster than the linearly increasing stock under the mattress (see figure 4). The amount added each year to a bank account or each 10 minutes to a yeast colony is not constant. It continually increases, as the total accumulated amount increases. Such exponential growth is a common process in biological, financial, and many other systems of the world.

Common as it is, exponential growth can yield surprising results—results that have fascinated mankind for centuries. There is an old Persian legend about a clever courtier who presented a beautiful chessboard to his king and requested that the king give him in return 1 grain of rice for the first square on the board, 2 grains for the second square, 4 grains for the third, and so forth. The king readily agreed and ordered rice to be brought from his stores. The fourth square of the chessboard required 8 grains, the tenth square took 512 grains, the fifteenth required 16,384, and the twenty-first square gave the courtier more than a million grains of rice. By the fortieth square a million million rice grains had to be brought from the storerooms. The king's entire rice supply was exhausted long before he reached the sixty-fourth square. Exponential increase is deceptive because it generates immense numbers very quickly.

A French riddle for children illustrates another aspect of exponential growth—the apparent suddenness with which it approaches a fixed limit. Suppose you own a pond on which a water lily is growing. The lily plant doubles in size each day. If the lily were allowed to grow unchecked, it would completely cover the pond in 30 days, choking off the other forms of life in the water. For a long time the lily plant seems small, and so you decide not to worry about cutting it back until it covers half the pond. On what day will that be? On the twenty-ninth day, of course. You have one day to save your pond.*

It is useful to think of exponential growth in terms of *doubling time,* or the time it takes a growing quantity to

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* We are indebted to M. Robert Lattes for telling us this riddle.

double in size. In the case of the lily plant described above, the doubling time is 1 day. A sum of money left in a bank at 7 percent interest will double in 10 years. There is a simple mathematical relationship between the interest rate, or rate of growth, and the time it will take a quantity to double in size. The doubling time is approximately equal to 70 divided by the growth rate, as illustrated in table 1.

Table 1 DOUBLING TIME

Growth rate (% per year)	*Doubling time (years)*
0.1	700
0.5	140
1.0	70
2.0	35
4.0	18
5.0	14
7.0	10
10.0	7

MODELS AND EXPONENTIAL GROWTH

Exponential growth is a dynamic phenomenon, which means that it involves elements that change over time. In simple systems, like the bank account or the lily pond, the cause of exponential growth and its future course are relatively easy to understand. When many different quantities are growing simultaneously in a system, however, and when all the quantities are interrelated in a complicated way, analysis of the causes of growth and of the future behavior of the system becomes very difficult indeed. Does population growth cause industrialization or does industrialization cause population growth? Is either one singly responsible for increasing pol-

lution, or are they both responsible? Will more food production result in more population? If any one of these elements grows slower or faster, what will happen to the growth rates of all the others? These very questions are being debated in many parts of the world today. The answers can be found through a better understanding of the entire complex system that unites all of these important elements.

Over the course of the last 30 years there has evolved at the Massachusetts Institute of Technology a new method for understanding the dynamic behavior of complex systems. The method is called System Dynamics.* The basis of the method is the recognition that the *structure* of any system—the many circular, interlocking, sometimes time-delayed relationships among its components—is often just as important in determining its behavior as the individual components themselves. The world model described in this book is a System Dynamics model.

Dynamic modeling theory indicates that any exponentially growing quantity is somehow involved with a *positive feedback loop*. A positive feedback loop is sometimes called a "vicious circle." An example is the familiar wage-price spiral—wages increase, which causes prices to increase, which leads to demands for higher wages, and so forth. In a positive feedback loop a chain of cause-and-effect relationships closes on itself, so that increasing any one element in the loop will start a sequence of changes that will result in the originally changed element being increased even more.

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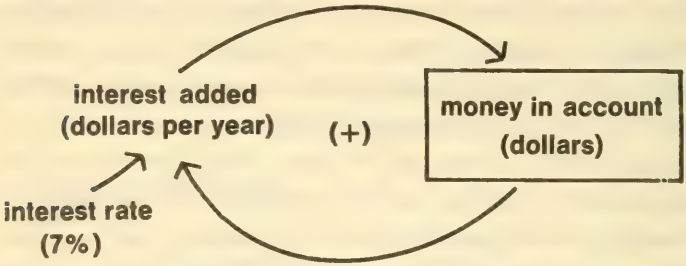
* A detailed description of the method of System Dynamics analysis is presented in J. W. Forrester's *Industrial Dynamics* (Cambridge, Mass.: MIT Press, 1961) and *Principles of Systems* (Cambridge, Mass.: Wright-Allen Press, 1968).

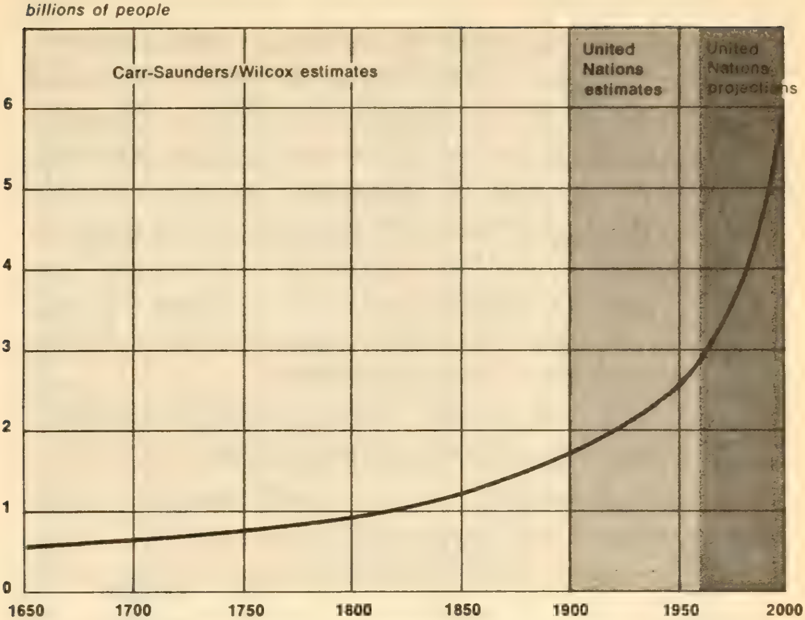
The positive feedback loop that accounts for exponential increase of money in a bank account can be represented like this:



Suppose $100 is deposited in the account. The first year's interest is 7 percent of $100, or $7, which is added to the account, making the total $107. The next year's interest is 7 percent of $107, or $7.49, which makes a new total of $114.49. One year later the interest on that amount will be more than $8.00. The more money there is in the account, the more money will be added each year in interest. The more is added, the more there will be in the account the next year causing even more to be added in interest. And so on. As we go around and around the loop, the accumulated money in the account grows exponentially. The rate of interest (constant at 7 percent) determines the gain around the loop, or the rate at which the bank account grows.

We can begin our dynamic analysis of the long-term world situation by looking for the positive feedback loops underlying the exponential growth in the five physical quantities we have already mentioned. In particular, the growth rates of two of these elements—population and industrialization—are of interest, since the goal of many development policies is to encourage the growth of the latter relative to the former. The

Figure 5 WORLD POPULATION



World population since 1650 has been growing exponentially at an increasing rate. Estimated population in 1970 is already slightly higher than the projection illustrated here (which was made in 1958). The present world population growth rate is about 2.1 percent per year, corresponding to a doubling time of 33 years.

SOURCE: Donald J. Bogue, *Principles of Demography* (New York: John Wiley and Sons, 1969).

two basic positive feedback loops that account for exponential population and industrial growth are simple in principle. We will describe their basic structures in the next few pages. The many interconnections between these two positive feedback loops act to amplify or to diminish the action of the loops, to couple or uncouple the growth rates of population and of industry. These interconnections constitute the rest of the world model and their description will occupy much of the rest of this book.

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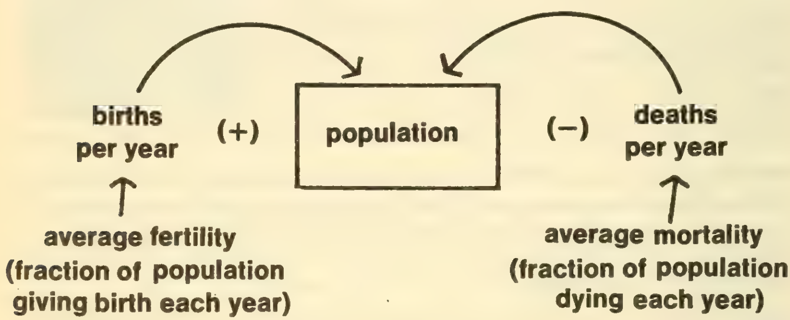
WORLD POPULATION GROWTH

The exponential growth curve of world population is shown in figure 5. In 1650 the population numbered about 0.5 billion,* and it was growing at a rate of approximately 0.3 percent per year.[1] That corresponds to a doubling time of nearly 250 years. In 1970 the population totaled 3.6 billion and the rate of growth was 2.1 percent per year.[2] The doubling time at this growth rate is 33 years. Thus, not only has the population been growing exponentially, but the rate of growth has also been growing. We might say that population growth has been "super"-exponential; the population curve is rising even faster than it would if growth were strictly exponential.

The feedback loop structure that represents the dynamic behavior of population growth is shown below.



On the left is the positive feedback loop that accounts for the observed exponential growth. In a population with constant average fertility, the larger the population, the more babies will be born each year. The more babies, the larger the popula-

* The word "billion" in this book will be used to mean 1000 million, i.e. the European "milliard."

[1] Notes begin on page 201.

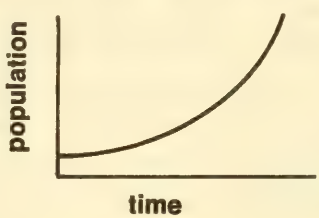
tion will be the following year. After a delay to allow those babies to grow up and become parents, even more babies will be born, swelling the population still further. Steady growth will continue as long as average fertility remains constant. If, in addition to sons, each woman has on the average two female children, for example, and each of them grows up to have two more female children, the population will double each generation. The growth rate will depend on both the average fertility and the length of the delay between generations. Fertility is not necessarily constant, of course, and in chapter III we will discuss some of the factors that cause it to vary.

There is another feedback loop governing population growth, shown on the right side of the diagram above. It is a *negative feedback loop.* Whereas positive feedback loops generate runaway growth, negative feedback loops tend to regulate growth and to hold a system in some stable state. They behave much as a thermostat does in controlling the temperature of a room. If the temperature falls, the thermostat activates the heating system, which causes the temperature to rise again. When the temperature reaches its limit, the thermostat cuts off the heating system, and the temperature begins to fall again. In a negative feedback loop a change in one element is propagated around the circle until it comes back to change that element in a direction *opposite* to the initial change.

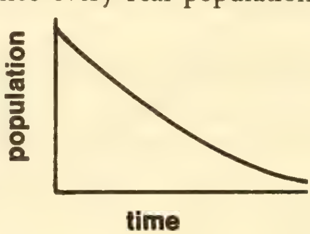
The negative feedback loop controlling population is based upon average mortality, a reflection of the general health of the population. The number of deaths each year is equal to the total population times the average mortality (whicn we might think of as the average probability of death at any age).

An increase in the size of a population with constant average mortality will result in more deaths per year. More deaths will leave fewer people in the population, and so there will be fewer deaths the next year. If on the average 5 percent of the population dies each year, there will be 500 deaths in a population of 10,000 in one year. Assuming no births for the moment, that would leave 9,500 people the next year. If the probability of death is still 5 percent, there will be only 475 deaths in this smaller population, leaving 9,025 people. The next year there will be only 452 deaths. Again, there is a delay in this feedback loop because the mortality rate is a function of the average age of the population. Also, of course, mortality even at a given age is not necessarily constant.

If there were no deaths in a population, it would grow exponentially by the positive feedback loop of births, as shown below. If there were no births, the population would decline



to zero because of the negative feedback loop of deaths, also as shown below. Since every real population experiences both

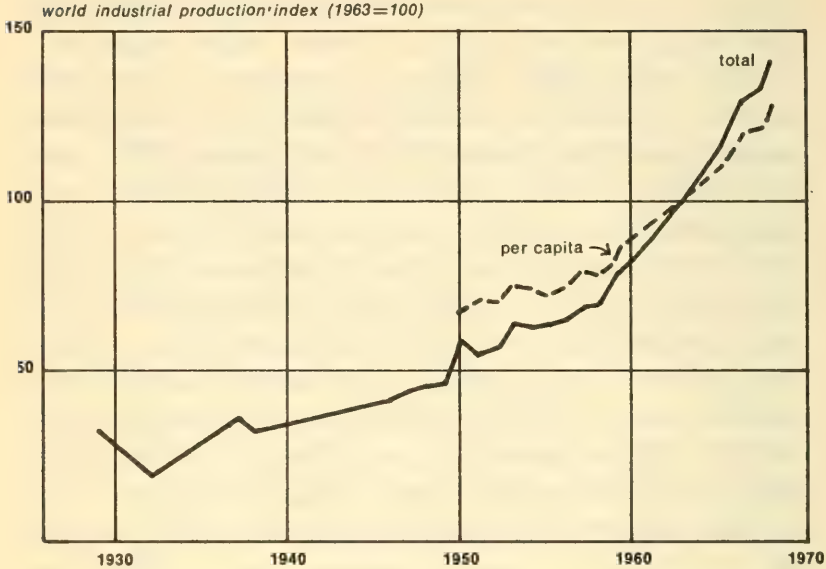


births and deaths, as well as varying fertility and mortality, the dynamic behavior of populations governed by these two interlocking feedback loops can become fairly complicated.

What has caused the recent super-exponential rise in world population? Before the industrial revolution both fertility and mortality were comparatively high and irregular. The birth rate generally exceeded the death rate only slightly, and population grew exponentially, but at a very slow and uneven rate. In 1650 the average lifetime of most populations in the world was only about 30 years. Since then, mankind has developed many practices that have had profound effects on the population growth system, especially on mortality rates. With the spread of modern medicine, public health techniques, and new methods of growing and distributing foods, death rates have fallen around the world. World average life expectancy is currently about 53 years[3] and still rising. On a world average the gain around the positive feedback loop (fertility) has decreased only slightly while the gain around the negative feedback loop (mortality) is decreasing. The result is an increasing dominance of the positive feedback loop and the sharp exponential rise in population pictured in figure 5.

What about the population of the future? How might we extend the population curve of figure 5 into the twenty-first century? We will have more to say about this in chapters III and IV. For the moment we can safely conclude that because of the delays in the controlling feedback loops, especially the positive loop of births, there is no possibility of leveling off the population growth curve before the year 2000, even with the most optimistic assumption of decreasing fertility. Most of the prospective parents of the year 2000 have already been born. Unless there is a sharp rise in mortality,

Figure 6 WORLD INDUSTRIAL PRODUCTION



World industrial production, relative to the base year 1963, also shows a clear exponential increase despite small fluctuations. The 1963-68 average growth rate of total production is 7 percent per year. The per capita growth rate is 5 percent per year.

SOURCES: UN Department of Economic and Social Affairs, *Statistical Yearbook 1956* and *Statistical Yearbook 1969* (New York: United Nations, 1957 and 1970).

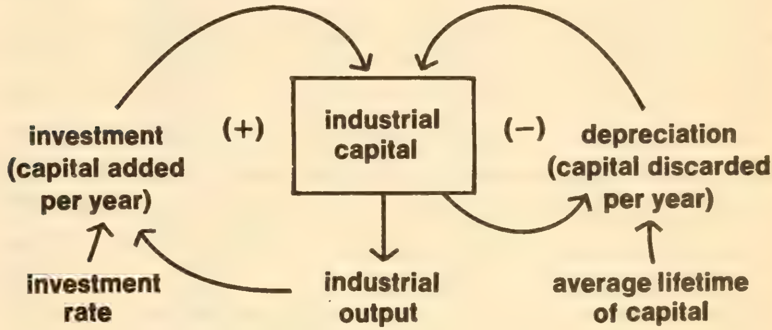
which mankind will certainly strive mightily to avoid, we can look forward to a world population of around 7 billion persons in 30 more years. And if we continue to succeed in lowering mortality with no better success in lowering fertility than we have accomplished in the past, in 60 years there will be four people in the world for every one person living today.

WORLD ECONOMIC GROWTH

A second quantity that has been increasing in the world even faster than human population is industrial output. Figure 6

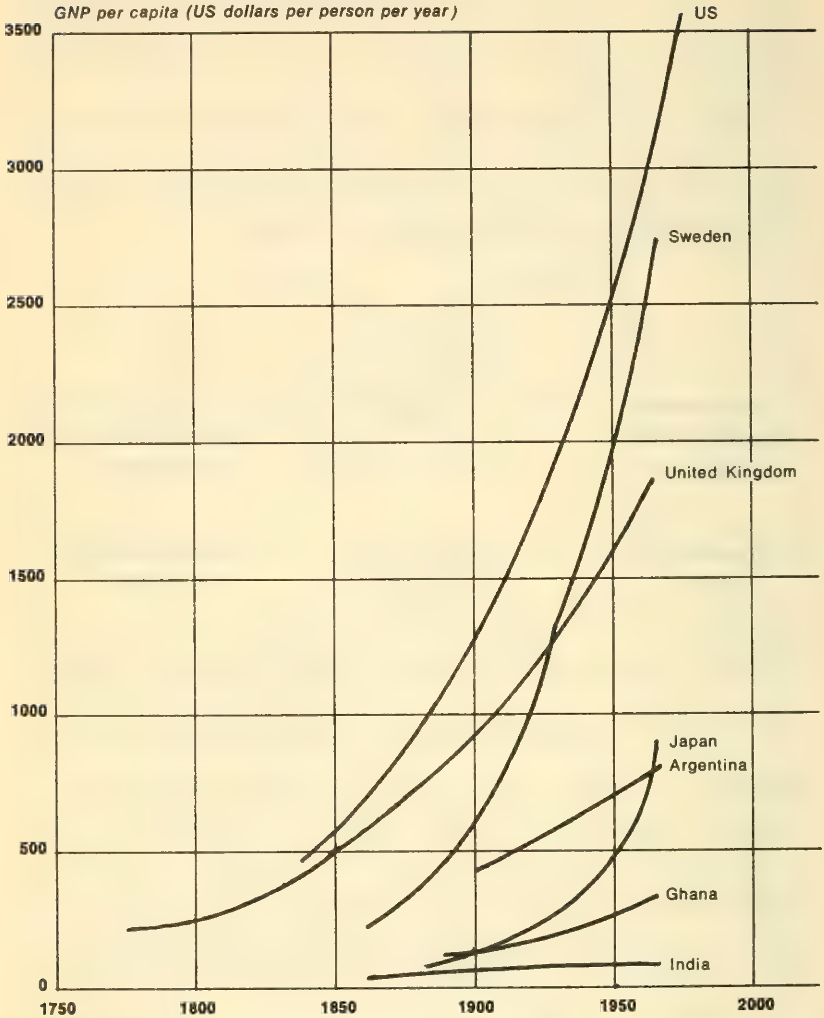
shows the expansion of world industrial production since 1930, with 1963 production as the base of reference. The average growth rate from 1963 to 1968 was 7 percent per year, or 5 percent per year on a per capita basis.

What is the positive feedback loop that accounts for exponential growth of industrial output? The dynamic structure, diagramed below, is actually very similar to the one we have already described for the population system.



With a given amount of industrial capital (factories, trucks, tools, machines, etc.), a certain amount of manufactured output each year is possible. The output actually produced is also dependent on labor, raw materials, and other inputs. For the moment we will assume that these other inputs are sufficient, so that capital is the limiting factor in production. (The world model does include these other inputs.) Much of each year's output is consumable goods, such as textiles, automobiles, and houses, that leave the industrial system. But some fraction of the production is more capital—looms, steel mills, lathes—which is an investment to increase the capital stock. Here we have another positive feedback loop. More capital creates more

Figure 7 ECONOMIC GROWTH RATES



The economic growth of individual nations indicates that differences in exponential growth rates are widening the economic gap between rich and poor countries.

SOURCE: Simon Kuznets, *Economic Growth of Nations* (Cambridge, Mass.: Harvard University Press, 1971).

output, some variable fraction of the output is investment, and more investment means more capital. The new, larger capital stock generates even more output, and so on. There are also delays in this feedback loop, since the production of a major piece of industrial capital, such as an electrical generating plant or a refinery, can take several years.

Capital stock is not permanent. As capital wears out or becomes obsolete, it is discarded. To model this situation we must introduce into the capital system a negative feedback loop accounting for capital depreciation. The more capital there is, the more wears out on the average each year; and the more that wears out, the less there will be the next year. This negative feedback loop is exactly analogous to the death rate loop in the population system. As in the population system, the positive loop is strongly dominant in the world today, and the world's industrial capital stock is growing exponentially.

Since industrial output is growing at 7 percent per year and population only at 2 percent per year, it might appear that dominant positive feedback loops are a cause for rejoicing. Simple extrapolation of those growth rates would suggest that the material standard of living of the world's people will double within the next 14 years. Such a conclusion, however, often includes the implicit assumption that the world's growing industrial output is evenly distributed among the world's citizens. The fallacy of this assumption can be appreciated when the per capita economic growth rates of some individual nations are examined (see figure 7).

Most of the world's industrial growth plotted in figure 6 is actually taking place in the already industrialized countries, where the rate of population growth is comparatively low.

Table 2 ECONOMIC AND POPULATION GROWTH RATES

Country	*Population (1968) (million)*	*Average annual growth rate of population (1961–68) (% per year)*	*GNP per capita (1968) (US dollars)*	*Average annual growth rate of GNP per capita (1961–68) (% per year)*
People's Republic of China *	730	1.5	90	0.3
India	524	2.5	100	1.0
USSR *	238	1.3	1,100	5.8
United States	201	1.4	3,980	3.4
Pakistan	123	2.6	100	3.1
Indonesia	113	2.4	100	0.8
Japan	101	1.0	1,190	9.9
Brazil	88	3.0	250	1.6
Nigeria	63	2.4	70	—0.3
Federal Republic of Germany	60	1.0	1,970	3.4

* The International Bank for Reconstruction and Development qualifies its estimates for China and the USSR with the following statement: "Estimates of GNP per capita and its growth rate have a wide margin of error mainly because of the problems in deriving the GNP at factor cost from net material product and in converting the GNP estimate into US dollars." United Nations estimates are in general agreement with those of the IBRD.

SOURCE: *World Bank Atlas* (Washington,DC: International Bank for Reconstruction and Development, 1970).

The most revealing possible illustration of that fact is a simple table listing the economic and population growth rates of the ten most populous nations of the world, where 64 percent of the world's population currently lives. Table 2 makes very clear the basis for the saying, "The rich get richer and the poor get children."

It is unlikely that the rates of growth listed in table 2 will continue unchanged even until the end of this century. Many

factors will change in the next 30 years. The end of civil disturbance in Nigeria, for example, will probably increase the economic growth rate there, while the onset of civil disturbance and then war in Pakistan has already interfered with economic growth there. Let us recognize, however, that the growth rates listed above are the products of a complicated social and economic system that is essentially stable and that is likely to change slowly rather than quickly, except in cases of severe social disruption.

It is a simple matter of arithmetic to calculate extrapolated values for gross national product (GNP) per capita from now until the year 2000 on the assumption that relative growth rates of population and GNP will remain roughly the same in these ten countries. The result of such a calculation appears in table 3. The values shown there will almost certainly *not* actually be realized. They are not predictions. The values merely indicate the general direction our system, as it is currently structured, is taking us. *They demonstrate that the process of*

Table 3 EXTRAPOLATED GNP FOR THE YEAR 2000

Country	*GNP per capita (in US dollars *)*
People's Republic of China	100
India	140
USSR	6,330
United States	11,000
Pakistan	250
Indonesia	130
Japan	23,200
Brazil	440
Nigeria	60
Federal Republic of Germany	5,850

* Based on the 1968 dollar with no allowance for inflation.

economic growth, as it is occurring today, is inexorably widening the absolute gap between the rich and the poor nations of the world.

Most people intuitively and correctly reject extrapolations like those shown in table 3, because the results appear ridiculous. It must be recognized, however, that in rejecting extrapolated values, one is also rejecting the assumption that there will be *no change* in the system. If the extrapolations in table 3 do not actually come to pass, it will be because the balance between the positive and negative feedback loops determining the growth rates of population and capital in each nation has been altered. Fertility, mortality, the capital investment rate, the capital depreciation rate—any or all may change. In postulating any different outcome from the one shown in table 3, one must specify which of these factors is likely to change, by how much, and when. These are exactly the questions we are addressing with our model, not on a national basis, but on an aggregated global one.

To speculate with any degree of realism on future growth rates of population and industrial capital, we must know something more about the other factors in the world that interact with the population-capital system. We shall begin by asking a very basic set of questions.

Can the growth rates of population and capital presented in table 3 be physically sustained in the world? How many people can be provided for on this earth, at what level of wealth, and for how long? To answer these questions, we must look in detail at those systems in the world which provide the physical support for population and economic growth.

CHAPTER II

THE LIMITS TO EXPONENTIAL GROWTH

For which of you, intending to build a tower, sitteth not down first, and counteth the cost, whether he have sufficient to finish it?

LUKE 14:28

What will be needed to sustain world economic and population growth until, and perhaps even beyond, the year 2000? The list of necessary ingredients is long, but it can be divided roughly into two main categories.

The first category includes the *physical* necessities that support all physiological and industrial activity—food, raw materials, fossil and nuclear fuels, and the ecological systems of the planet which absorb wastes and recycle important basic chemical substances. These ingredients are in principle tangible, countable items, such as arable land, fresh water, metals, forests, the oceans. In this chapter we will assess the world's stocks of these physical resources, since they are the ultimate determinants of the limits to growth on this earth.

The second category of necessary ingredients for growth consists of the *social* necessities. Even if the earth's physical systems are capable of supporting a much larger, more econom-

ically developed population, the actual growth of the economy and of the population will depend on such factors as peace and social stability, education and employment, and steady technological progress. These factors are much more difficult to assess or to predict. Neither this book nor our world model at this stage in its development can deal explicitly with these social factors, except insofar as our information about the quantity and distribution of physical supplies can indicate possible future social problems.

Food, resources, and a healthy environment are necessary but not sufficient conditions for growth. Even if they are abundant, growth may be stopped by social problems. Let us assume for the moment, however, that the best possible social conditions will prevail. How much growth will the physical system then support? The answer we obtain will give us some estimate of the upper limits to population and capital growth, but no guarantee that growth will actually proceed that far.

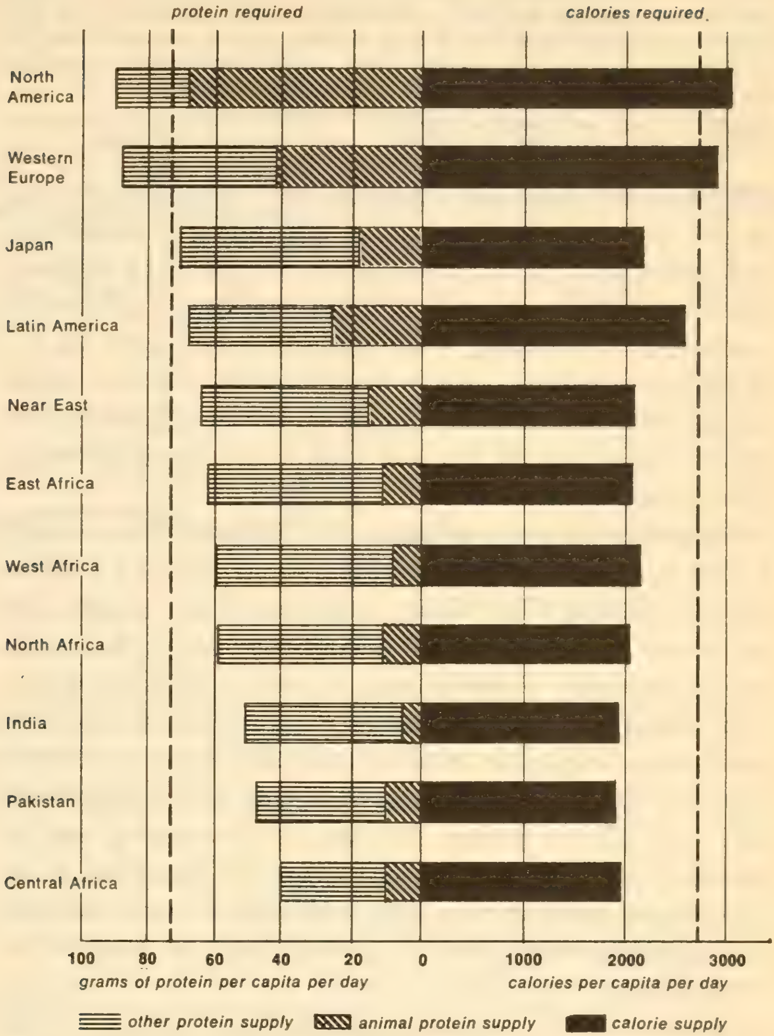
FOOD

In Zambia, in Africa, 260 of every thousand babies born are dead before their first birthday. In India and Pakistan the ratio is 140 of every thousand; in Colombia it is 82. Many more die before they reach school age; others during the early school years.

Where death certificates are issued for preschool infants in the poor countries, death is generally attributed to measles, pneumonia, dysentery, or some other disease. In fact these children are more likely to be the victims of malnutrition.[4]

No one knows exactly how many of the world's people are inadequately nourished today, but there is general agreement that the number is large—perhaps 50 to 60 percent of the population of the less industrialized countries,[5] which means one-third of the population of the world. Estimates by the

Figure 8 PROTEIN AND CALORIC INTAKE



Daily protein and calorie requirements are not being supplied to most areas of the world. Inequalities of distribution exist not only among regions, as shown here, but also within regions. According to the UN Food and Agriculture Organization, areas of greatest shortage include the

"Andean countries, the semi-arid stretches of Africa and the Near East, and some densely populated countries of Asia." Lines indicating calories and proteins required are those estimated for North Americans. The assumption has been made that if diets in other regions were sufficient to allow people to reach full potential body weight, requirements would be the same everywhere.

SOURCE: UN Food and Agriculture Organization, *Provisional Indicative World Plan for Agricultural Development* (Rome: UN Food and Agriculture Organization, 1970).

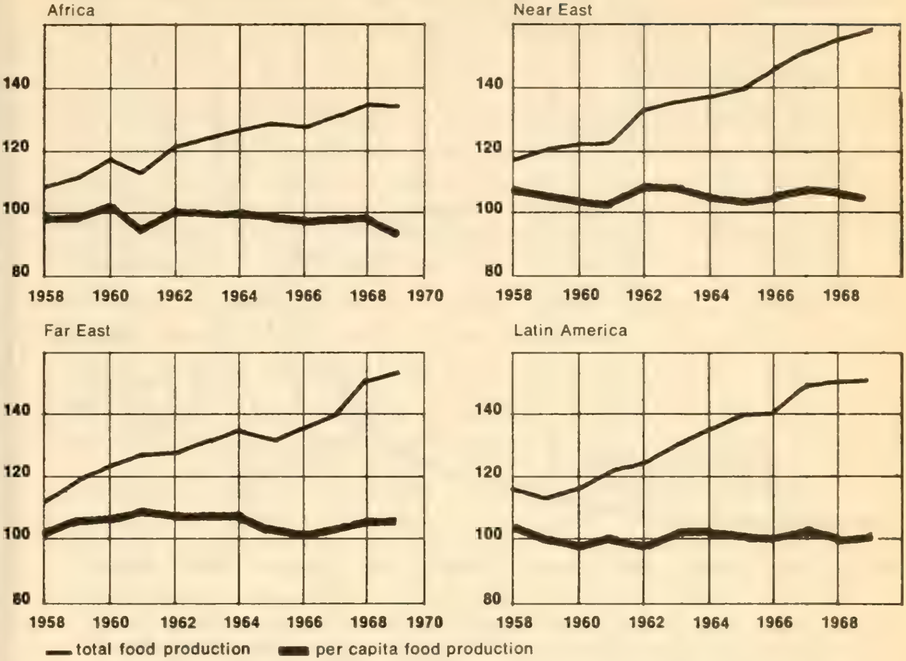
UN Food and Agriculture Organization (FAO) indicate that in most of the developing countries basic caloric requirements, and particularly protein requirements, are not being supplied (see figure 8). Furthermore, although total world agricultural production is increasing, food production *per capita* in the nonindustrialized countries is barely holding constant at its present inadequate level (see figure 9). Do these rather dismal statistics mean that the limits of food production on the earth have already been reached?

The primary resource necessary for producing food is land. Recent studies indicate that there are, at most, about 3.2 billion hectares of land (7.86 billion acres) potentially suitable for agriculture on the earth.[6] Approximately half of that land, the richest, most accessible half, is under cultivation today. The remaining land will require immense capital inputs to reach, clear, irrigate, or fertilize before it is ready to produce food. Recent costs of developing new land have ranged from $215 to $5,275 per hectare. Average cost for opening land in unsettled areas has been $1,150 per hectare.[7] According to an FAO report, opening more land to cultivation is not economically feasible, even given the pressing need for food in the world today:

In Southern Asia . . . in some countries in Eastern Asia, in the Near East and North Africa, and in certain parts of Latin America and Africa . . . there is almost no scope for expanding the arable area.

Figure 9 FOOD PRODUCTION

regional average food production index (1952 - 56 = 100)



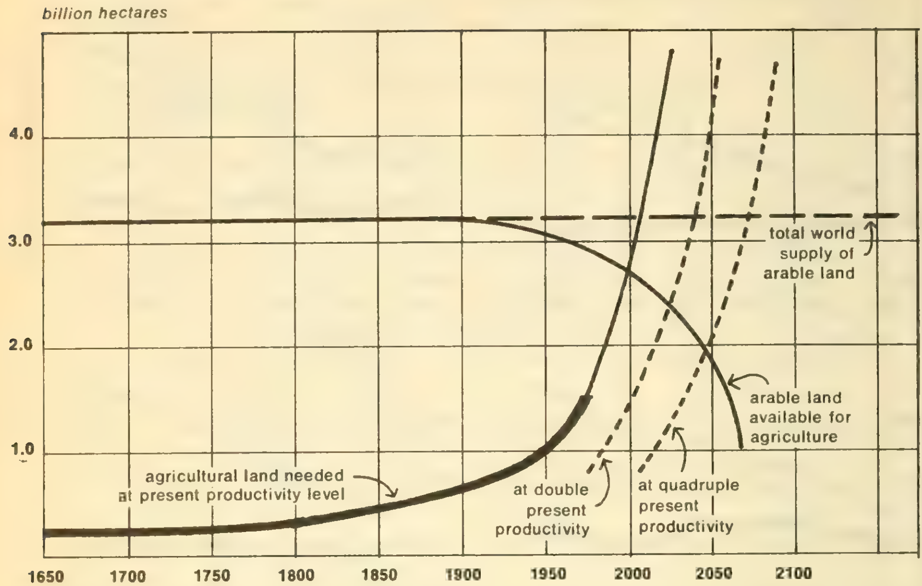
Total food production in the nonindustrialized regions of the world has risen at about the same rate as the population. Thus food production ***per capita*** *has remained nearly constant, at a low level.*

SOURCE: UN Food and Agriculture Organization, *The State of Food and Agriculture 1970* (Rome: UN Food and Agriculture Organization, 1970).

. . . In the dryer regions it will even be necessary to return to permanent pasture the land which is marginal or submarginal for cultivation. In most of Latin America and Africa South of the Sahara there are still considerable possibilities for expanding cultivated area, but the costs of development are high and it will be often more economical to intensify utilization of the areas already settled.[8]

If the world's people did decide to pay the high capital costs, to cultivate all possible arable land, and to produce as much food as possible, how many people could theoretically be fed?

Figure 10 ARABLE LAND



Total world supply of arable land is about 3.2 billion hectares. About 0.4 hectares per person of arable land are needed at present productivity. The curve of land needed thus reflects the population growth curve. The light line after 1970 shows the projected need for land, assuming that world population continues to grow at its present rate. Arable land available decreases because arable land is removed for urban-industrial use as population grows. The dotted curves show land needed if present productivity is doubled or quadrupled.

The lower curve in figure 10 shows the amount of land needed to feed the growing world population, assuming that the present world average of 0.4 hectares per person is sufficient. (To feed the entire world population at present US standards, 0.9 hectares per person would be required.) The upper curve in figure 10 shows the actual amount of land available over time. This line slopes downward because each additional person requires a certain amount of land (0.08 hectares per

person assumed here*) for housing, roads, waste disposal, power lines, and other uses that essentially "pave" arable land and make it unusable for food production. Land loss through erosion is not shown here, but it is by no means negligible. Figure 10 shows that, even with the optimistic assumption that all possible land is utilized, there will still be a desperate land shortage before the year 2000 if per capita land requirements and population growth rates remain as they are today.

Figure 10 also illustrates some very important general facts about exponential growth within a limited space. First, it shows how one can move within a very few years from a situation of great abundance to one of great scarcity. There has been an overwhelming excess of potentially arable land for all of history, and now, within 30 years (or about one population doubling time), there may be a sudden and serious shortage. Like the owner of the lily pond in our example in chapter I, the human race may have very little time to react to a crisis resulting from exponential growth in a finite space.

A second lesson to be learned from figure 10 is that precise numerical assumptions about the limits of the earth are unimportant when viewed against the inexorable progress of exponential growth. We might assume, for example, that *no* arable land is taken for cities, roads, or other nonagricultural uses. In that case, the land available is constant, as shown by the horizontal dashed line. The point at which the two curves cross is delayed by about 10 years. Or we can suppose that it is possible to double, or even quadruple, the productivity of the land through advances in agricultural technology and in-

* Aerial surveys of forty-four counties in the western United States from 1950 to 1960 indicate that built-on land ranged from .008 to .174 hectares per person.[9]

vestments in capital, such as tractors, fertilizer, and irrigation systems. The effects of two different assumptions about increased productivity are shown by the dotted lines in figure 10. Each doubling of productivity gains about 30 years, or less than one population doubling time.

Of course, society will not be suddenly surprised by the "crisis point" at which the amount of land needed becomes greater than that available. Symptoms of the crisis will begin to appear long before the crisis point is reached. Food prices will rise so high that some people will starve; others will be forced to decrease the effective amount of land they use and shift to lower quality diets. These symptoms are already apparent in many parts of the world. Although only half the land shown in figure 10 is now under cultivation, perhaps 10 to 20 million deaths each year can be attributed directly or indirectly to malnutrition.[10]

There is no question that many of these deaths are due to the world's social limitations rather than its physical ones. Yet there is clearly a link between these two kinds of limitations in the food-producing system. If good fertile land were still easily reached and brought under cultivation, there would be no economic barrier to feeding the hungry, and no difficult social choices to make. The best half of the world's potentially arable land is already cultivated, however, and opening new land is already so costly that society has judged it "uneconomic." This is a social problem exacerbated by a physical limitation.

Even if society did decide to pay the necessary costs to gain new land or to increase productivity of the land already cultivated, figure 10 shows how quickly rising population would bring about another "crisis point." And each successive crisis point will cost more to overcome. Each doubling of yield

from the land will be more expensive than the last one. We might call this phenomenon the law of increasing costs. The best and most sobering example of that law comes from an assessment of the cost of past agricultural gains. To achieve a 34 percent increase in world food production from 1951 to 1966, agriculturalists increased yearly expenditures on tractors by 63 percent, annual investment in nitrate fertilizers by 146 percent, and annual use of pesticides by 300 percent.[11] The next 34 percent increase will require even greater inputs of capital and resources.

How many people can be fed on this earth? There is, of course, no simple answer to this question. The answer depends on the choices society makes among various available alternatives. There is a direct trade-off between producing more food and producing other goods and services needed or desired by mankind. The demand for these other goods and services is also increasing as population grows, and therefore the trade-off becomes continuously more apparent and more difficult to resolve. Even if the choice were consistently to produce food as the first priority, however, continued population growth and the law of increasing costs could rapidly drive the system to the point where all available resources were devoted to producing food, leaving no further possibility of expansion.

In this section we have discussed only one possible limit to food production—arable land. There are other possible limits, but space does not permit us to discuss them in detail here. The most obvious one, second in importance only to land, is the availability of fresh water. There is an upper limit to the fresh water runoff from the land areas of the earth each year, and there is also an exponentially increasing demand for that water. We could draw a graph exactly analogous to figure 10

to show the approach of the increasing demand curve for water to the constant average supply. In some areas of the world, this limit will be reached long before the land limit becomes apparent.

It is also possible to avoid or extend these limits by technological advances that remove dependence on the land (synthetic food) or that create new sources of fresh water (desalinization of sea water). We shall discuss such innovations further in chapter IV. For the moment it is sufficient to recognize that no new technology is spontaneous or without cost. The factories and raw materials to produce synthetic food, the equipment and energy to purify sea water must all come from the physical world system.

The exponential growth of *demand* for food results directly from the positive feedback loop that is now determining the growth of human population. The *supply* of food to be expected in the future is dependent on land and fresh water and also on agricultural capital, which depends in turn on the other dominant positive feedback loop in the system—the capital investment loop. Opening new land, farming the sea, or expanding use of fertilizers and pesticides will require an increase of the capital stock devoted to food production. The resources that permit growth of that capital stock tend not to be renewable resources, like land or water, but nonrenewable resources, like fuels or metals. Thus the expansion of food production in the future is very much dependent on the availability of nonrenewable resources. Are there limits to the earth's supply of these resources?

NONRENEWABLE RESOURCES

Even taking into account such economic factors as increased prices with decreasing availability, it would appear at present that the quanti-

ties of platinum, gold, zinc, and lead are not sufficient to meet demands. At the present rate of expansion . . . silver, tin, and uranium may be in short supply even at higher prices by the turn of the century. By the year 2050, several more minerals may be exhausted if the current rate of consumption continues.

Despite spectacular recent discoveries, there are only a limited number of places left to search for most minerals. Geologists disagree about the prospects for finding large, new, rich ore deposits. Reliance on such discoveries would seem unwise in the long term.[12]

Table 4 lists some of the more important mineral and fuel resources, the vital raw materials for today's major industrial processes. The number following each resource in column 3 is the static reserve index, or the number of years present known reserves of that resource (listed in column 2) will last at the *current* rate of usage. This static index is the measure normally used to express future resource availability. Underlying the static index are several assumptions, one of which is that the usage rate will remain constant.

But column 4 in table 4 shows that the world usage rate of every natural resource is growing exponentially. For many resources the usage rate is growing even faster than the population, indicating both that more people are consuming resources each year and also that the average consumption per person is increasing each year. In other words, the exponential growth curve of resource consumption is driven by both the positive feedback loops of population growth and of capital growth.

We have already seen in figure 10 that an exponential increase in land use can very quickly run up against the fixed amount of land available. An exponential increase in resource consumption can rapidly diminish a fixed store of resources in the same way. Figure 11, which is similar to figure 10, illus-

Table 4 NONRENEWABLE NATURAL RESOURCES

1	2	3	4			5	6
Resource	*Known Global Reserves* [a]	*Static Index (years)* [b]	*Projected Rate of Growth (% per Year)* [c]			*Exponential Index (years)* [d]	*Exponential Index Calculated Using 5 Times Known Reserves (years)* [e]
			High	*Av.*	*Low*		
Aluminum	1.17×10^9 tons [j]	100	7.7	6.4	5.1	31	55
Chromium	7.75×10^8 tons	420	3.3	2.6	2.0	95	154
Coal	5×10^{12} tons	2300	5.3	4.1	3.0 [k]	111	150
Cobalt	4.8×10^9 lbs	110	2.0	1.5	1.0	60	148
Copper	308×10^6 tons	36	5.8	4.6	3.4	21	48
Gold	353×10^6 troy oz	11	4.8	4.1	3.4 [l]	9	29
Iron	1×10^{11} tons	240	2.3	1.8	1.3	93	173
Lead	91×10^6 tons	26	2.4	2.0	1.7	21	64
Manganese	8×10^8 tons	97	3.5	2.9	2.4	46	94
Mercury	3.34×10^6 flasks	13	3.1	2.6	2.2	13	41

7	8	9	10
Countries or Areas with Highest Reserves (% of world total)[f]	*Prime Producers (% of world total)*[g]	*Prime Consumers (% of world total)*[h]	*US Consumption as % of World Total*[i]
Australia (33) Guinea (20) Jamaica (10)	Jamaica (19) Surinam (12)	US (42) USSR (12)	42
Rep. of S. Africa (75)	USSR (30) Turkey (10)		19
US (32) USSR-China (53)	USSR (20) US (13)		44
Rep. of Congo (31) Zambia (16)	Rep. of Congo (51)		32
US (28) Chile (19)	US (20) USSR (15) Zambia (13)	US (33) USSR (13) Japan (11)	33
Rep. of S. Africa (40)	Rep. of S. Africa (77) Canada (6)		26
USSR (33) S. Am. (18) Canada (14)	USSR (25) US (14)	US (28) USSR (24) W. Germany (7)	28
US (39)	USSR (13) Australia (13) Canada (11)	US (25) USSR (13) W. Germany (11)	25
Rep. of S. Africa (38) USSR (25)	USSR (34) Brazil (13) Rep. of S. Africa (13)		14
Spain (30) Italy (21)	Spain (22) Italy (21) USSR (18)		24

1	2	3	4			5	6
Resource	*Known Global Reserves* [a]	*Static Index (years)* [b]	*Projected Rate of Growth (% per Year)* [c]			*Exponential Index (years)* [d]	*Exponential Index Calculated Using 5 Times Known Reserves (years)*
			High	*Av.*	*Low*		
Molybdenum	10.8×10^9 lbs	79	5.0	4.5	4.0	34	65
Natural Gas	1.14×10^{15} cu ft	38	5.5	4.7	3.9	22	49
Nickel	147×10^9 lbs	150	4.0	3.4	2.8	53	96
Petroleum	455×10^9 bbls	31	4.9	3.9	2.9	20	50
Platinum Group [m]	429×10^6 troy oz	130	4.5	3.8	3.1	47	85
Silver	5.5×10^9 troy oz	16	4.0	2.7	1.5	13	42
Tin	4.3×10^6 lg tons	17	2.3	1.1	0	15	61
Tungsten	2.9×10^9 lbs	40	2.9	2.5	2.1	28	72
Zinc	123×10^6 tons	23	3.3	2.9	2.5	18	50

7	8	9	10
Countries or Areas with Highest Reserves (% of world total)[f]	*Prime Producers (% of world total)*[g]	*Prime Consumers (% of world total)*[h]	*US Consumption as % of World Total*[i]
US (58) USSR (20)	US (64) Canada (14)		40
US (25) USSR (13)	US (58) USSR (18)		63
Cuba (25) New Caledonia (22) USSR (14) Canada (14)	Canada (42) New Caledonia (28) USSR (16)		38
Saudi Arabia (17) Kuwait (15)	US (23) USSR (16)	US (33) USSR (12) Japan (6)	33
Rep. of S. Africa (47) USSR (47)	USSR (59)		31
Communist Countries (36) US (24)	Canada (20) Mexico (17) Peru (16)	US (26) W. Germany (11)	26
Thailand (33) Malaysia (14)	Malaysia (41) Bolivia (16) Thailand (13)	US (24) Japan (14)	24
China (73)	China (25) USSR (19) US (14)		22
US (27) Canada (20)	Canada (23) USSR (11) US (8)	US (26) Japan (13) USSR (11)	26

[a] SOURCE: US Bureau of Mines, *Mineral Facts and Problems, 1970* (Washington, DC: Government Printing Office, 1970).

[b] The number of years known global reserves will last at current global consumption. Calculated by dividing known reserves (column 2) by the current annual consumption (US Bureau of Mines, *Mineral Facts and Problems, 1970*).

[c] SOURCE: US Bureau of Mines, *Mineral Facts and Problems, 1970.*

[d] The number of years known global reserves will last with consumption growing exponentially at the average annual rate of growth. Calculated by the formula

$$\text{exponential index} = \frac{\ln((r \cdot s) + 1)}{r}$$

where r = average rate of growth from column 4
s = static index from column 3.

[e] The number of years that five times known global reserves will last with consumption growing exponentially at the average annual rate of growth. Calculated from the above formula with 5s in place of s.

[f] SOURCE: US Bureau of Mines, *Mineral Facts and Problems, 1970.*

[g] SOURCE: UN Department of Economic and Social Affairs, *Statistical Yearbook 1969* (New York: United Nations, 1970).

[h] SOURCES: *Yearbook of the American Bureau of Metal Statistics 1970* (York, Pa.: Maple Press, 1970).
World Petroleum Report (New York: Mona Palmer Publishing, 1968).
UN Economic Commission for Europe, *The World Market for Iron Ore* (New York: United Nations, 1968).
US Bureau of Mines, *Mineral Facts and Problems, 1970.*

[i] SOURCE: US Bureau of Mines, *Mineral Facts and Problems, 1970.*

[j] Bauxite expressed in aluminum equivalent.

[k] US Bureau of Mines contingency forecasts, based on assumptions that coal will be used to synthesize gas and liquid fuels.

[l] Includes US Bureau of Mines estimates of gold demand for hoarding.

[m] The platinum group metals are platinum, palladium, iridium, osmium, rhodium, and ruthenium.

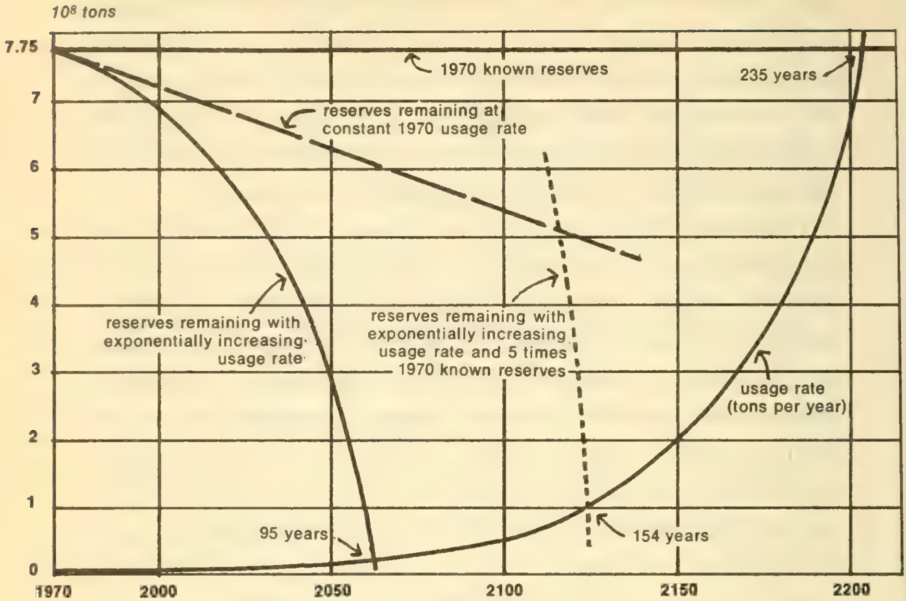
ADDITIONAL SOURCES:
P. T. Flawn, *Mineral Resources* (Skokie, Ill.: Rand McNally, 1966).
Metal Statistics (Somerset, NJ: American Metal Market Company, 1970).
US Bureau of Mines, *Commodity Data Summary* (Washington, DC: Government Printing Office, January 1971).

trates the effect of exponentially increasing consumption of a given initial amount of a nonrenewable resource. The example in this case is chromium ore, chosen because it has one of the longest static reserve indices of all the resources listed in table 4. We could draw a similar graph for each of the resources listed in the table. The time scales for the resources would vary, but the general shape of the curves would be the same.

The world's known reserves of chromium are about 775 million metric tons, of which about 1.85 million metric tons are mined annually at present.[13] Thus, at the current rate of use, the known reserves would last about 420 years. The dashed line in figure 11 illustrates the linear depletion of chromium reserves that would be expected under the assumption of constant use. The actual world consumption of chromium is increasing, however, at the rate of 2.6 percent annually.[13] The curved solid lines in figure 11 show how that growth rate, if it continues, will deplete the resource stock, not in 420 years, as the linear assumption indicates, but in just 95 years. If we suppose that reserves yet undiscovered could increase present known reserves by a factor of five, as shown by the dotted line, this fivefold increase would extend the lifetime of the reserves only from 95 to 154 years. Even if it were possible from 1970 onward to recycle 100 percent of the chromium (the horizontal line) so that none of the initial reserves were lost, the demand would exceed the supply in 235 years.

Figure 11 shows that under conditions of exponential growth in resource consumption, the static reserve index (420 years for chromium) is a rather misleading measure of resource availability. We might define a new index, an "exponential reserve index," which gives the probable lifetime of each resource, assuming that the current growth rate in consumption will

Figure 11 CHROMIUM RESERVES



The lifetime of known chromium reserves depends on the future usage rate of chromium. If usage remains constant, reserves will be depleted linearly (dashed line) and will last 420 years. If usage increases exponentially at its present growth rate of 2.6 percent per year, reserves will be depleted in just 95 years. If actual reserves are five times present proven reserves, chromium ore will be available for 154 years (dotted line), assuming exponential growth in usage. Even if all chromium is perfectly recycled, starting in 1970, exponentially growing demand will exceed the supply after 235 years (horizontal line).

continue. We have included this index in column 5 of table 4. We have also calculated an exponential index on the assumption that our present known reserves of each resource can be expanded fivefold by new discoveries. This index is shown in column 6. The effect of exponential growth is to reduce the probable period of availability of aluminum, for example, from 100 years to 31 years (55 years with a fivefold increase in reserves). Copper, with a 36-year lifetime at the present usage

rate, would actually last only 21 years at the present rate of growth, and 48 years if reserves are multiplied by five. It is clear that the present exponentially growing usage rates greatly diminish the length of time that wide-scale economic growth can be based on these raw materials.

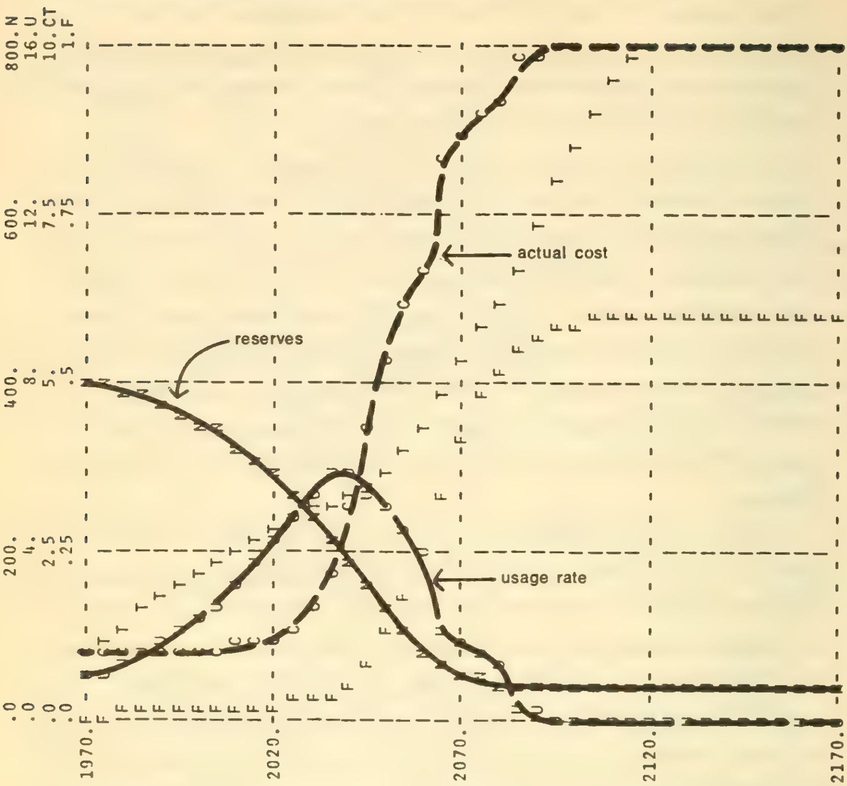
Of course the actual nonrenewable resource availability in the next few decades will be determined by factors much more complicated than can be expressed by either the simple static reserve index or the exponential reserve index. We have studied this problem with a detailed model that takes into account the many interrelationships among such factors as varying grades of ore, production costs, new mining technology, the elasticity of consumer demand, and substitution of other resources.* Illustrations of the general conclusions of this model follow.

Figure 12 is a computer plot indicating the future availability of a resource with a 400-year static reserve index in the year 1970, such as chromium. The horizontal axis is time in years; the vertical axis indicates several quantities, including the amount of reserves remaining (labeled RESERVES), the amount used each year (USAGE RATE), the extraction cost per unit of resource (ACTUAL COST), the advance of mining and processing technology (indicated by a T), and the fraction of original use of the resource that has been shifted to a substitute resource (F).

At first the annual consumption of chromium grows exponentially, and the stock of the resource is rapidly depleted. The price of chromium remains low and constant because new developments in mining technology allow efficient use of lower

* A more complete description of this model is presented in the papers by William W. Behrens III listed in the appendix.

Figure 12 CHROMIUM AVAILABILITY

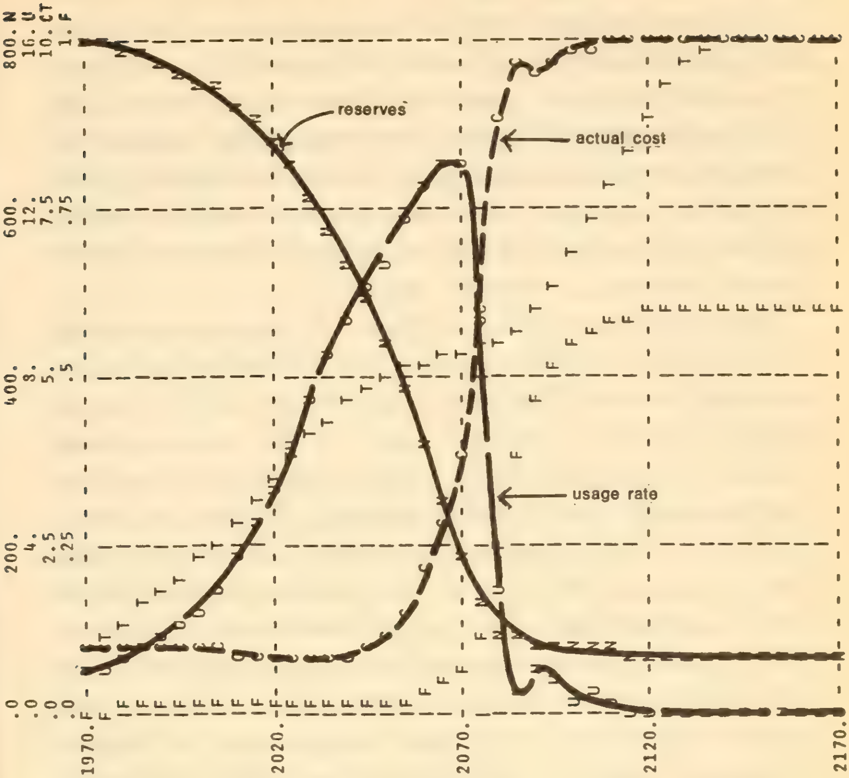


This figure presents a computer calculation of the economic factors in the availability of a resource (chromium) with a 400-year static reserve index. Exponential growth in consumption is eventually stopped by rising costs as initial reserves are depleted, even though the technology of extraction and processing is also increasing exponentially. The usage rate falls to zero after 125 years, at which point 60 percent of the original uses have been substituted by another resource.

SOURCE: William W. Behrens III, "The Dynamics of Natural Resource Utilization." Paper presented at the 1971 Computer Simulation Conference, Boston, Massachusetts, July 1971.

and lower grades of ore. As demand continues to increase, however, the advance of technology is not fast enough to counteract the rising costs of discovery, extraction, processing,

Figure 13 CHROMIUM AVAILABILITY WITH DOUBLE THE KNOWN RESERVES



If a discovery in 1970 doubles the known reserves of the resource (static reserve index 800 years), exponential growth in the usage rate is prolonged, and the usage rate reaches a high value. Reserves are depleted very rapidly during the peak in usage rate, however. Because of this rapid depletion, the effect of doubling the reserves is not to double the resource lifetime, but merely to extend it from 125 to 145 years.

SOURCE: William W. Behrens, III, "The Dynamics of Natural Resource Utilization."

and distribution. Price begins to rise, slowly at first and then very rapidly. The higher price causes consumers to use chromium more efficiently and to substitute other metals for chromium whenever possible. After 125 years, the remaining chromium, about 5 percent of the original supply, is available

only at prohibitively high cost, and mining of new supplies has fallen essentially to zero.

This more realistic dynamic assumption about the future use of chromium yields a probable lifetime of 125 years, which is considerably shorter than the lifetime calculated from the static assumption (400 years), but longer than the lifetime calculated from the assumption of constant exponential growth (95 years). The usage rate in the dynamic model is neither constant nor continuously increasing, but bell-shaped, with a growth phase and a phase of decline.

The computer run shown in figure 13 illustrates the effect of a discovery in 1970 that *doubles* the remaining known chromium reserves. The static reserve index in 1970 becomes 800 years instead of 400. As a result of this discovery, costs remain low somewhat longer, so that exponential growth can continue longer than it did in figure 12. The period during which use of the resource is economically feasible is increased from 125 years to 145 years. In other words, a *doubling* of the reserves increases the actual period of use by only 20 years.

The earth's crust contains vast amounts of those raw materials which man has learned to mine and to transform into useful things. However vast those amounts may be, they are not infinite. Now that we have seen how suddenly an exponentially growing quantity approaches a fixed upper limit, the following statement should not come as a surprise. *Given present resource consumption rates and the projected increase in these rates, the great majority of the currently important nonrenewable resources will be extremely costly 100 years from now.* The above statement remains true regardless of the most optimistic assumptions about undiscovered reserves, technological advances, substitution, or recycling, as long as the

demand for resources continues to grow exponentially. The prices of those resources with the shortest static reserve indices have already begun to increase. The price of mercury, for example, has gone up 500 percent in the last 20 years; the price of lead has increased 300 percent in the last 30 years.[14]

The simple conclusions we have drawn by considering total world reserves of resources are further complicated by the fact that neither resource reserves nor resource consumption are distributed evenly about the globe. The last four columns of table 4 show clearly that the industrialized, consuming countries are heavily dependent on a network of international agreements with the producing countries for the supply of raw materials essential to their industrial base. Added to the difficult economic question of the fate of various industries as resource after resource becomes prohibitively expensive is the imponderable political question of the relationships between producer and consumer nations as the remaining resources become concentrated in more limited geographical areas. Recent nationalization of South American mines and successful Middle Eastern pressures to raise oil prices suggest that the political question may arise long before the ultimate economic one.

Are there enough resources to allow the economic development of the 7 billion people expected by the year 2000 to a reasonably high standard of living? Once again the answer must be a conditional one. It depends on how the major resource-consuming societies handle some important decisions ahead. They might continue to increase resource consumption according to the present pattern. They might learn to reclaim and recycle discarded materials. They might develop new designs to increase the durability of products made from scarce

resources. They might encourage social and economic patterns that would satisfy the needs of a person while minimizing, rather than maximizing, the irreplaceable substances he possesses and disperses.

All of these possible courses involve trade-offs. The trade-offs are particularly difficult in this case because they involve choosing between present benefits and future benefits. In order to guarantee the availability of adequate resources in the future, policies must be adopted that will decrease resource use in the present. Most of these policies operate by raising resource costs. Recycling and better product design are expensive; in most parts of the world today they are considered "uneconomic." Even if they were effectively instituted, however, as long as the driving feedback loops of population and industrial growth continue to generate more people and a higher resource demand per capita, the system is being pushed toward its limit—the depletion of the earth's nonrenewable resources.

What happens to the metals and fuels extracted from the earth after they have been used and discarded? In one sense they are never lost. Their constituent atoms are rearranged and eventually dispersed in a diluted and unusable form into the air, the soil, and the waters of our planet. The natural ecological systems can absorb many of the effluents of human activity and reprocess them into substances that are usable by, or at least harmless to, other forms of life. When any effluent is released on a large enough scale, however, the natural absorptive mechanisms can become saturated. The wastes of human civilization can build up in the environment until they become visible, annoying, and even harmful. Mercury in ocean fish, lead particles in city air, mountains of urban trash, oil slicks on beaches—these are the results of the increasing flow of

resources into and out of man's hands. It is little wonder, then, that another exponentially increasing quantity in the world system is pollution.

POLLUTION

Many people . . . are concluding on the basis of mounting and reasonably objective evidence that the length of life of the biosphere as an inhabitable region for organisms is to be measured in decades rather than in hundreds of millions of years. This is entirely the fault of our own species.[15]

Man's concern for the effect of his activities on the natural environment is only very recent. Scientific attempts to measure this effect are even more recent and still very incomplete. We are certainly not able, at this time, to come to any final conclusion about the earth's capacity to absorb pollution. We can, however, make four basic points in this section, which illustrate, from a dynamic, global perspective, how difficult it will be to understand and control the future state of our ecological systems. These points are:

1. The few kinds of pollution that actually have been measured over time seem to be increasing exponentially.

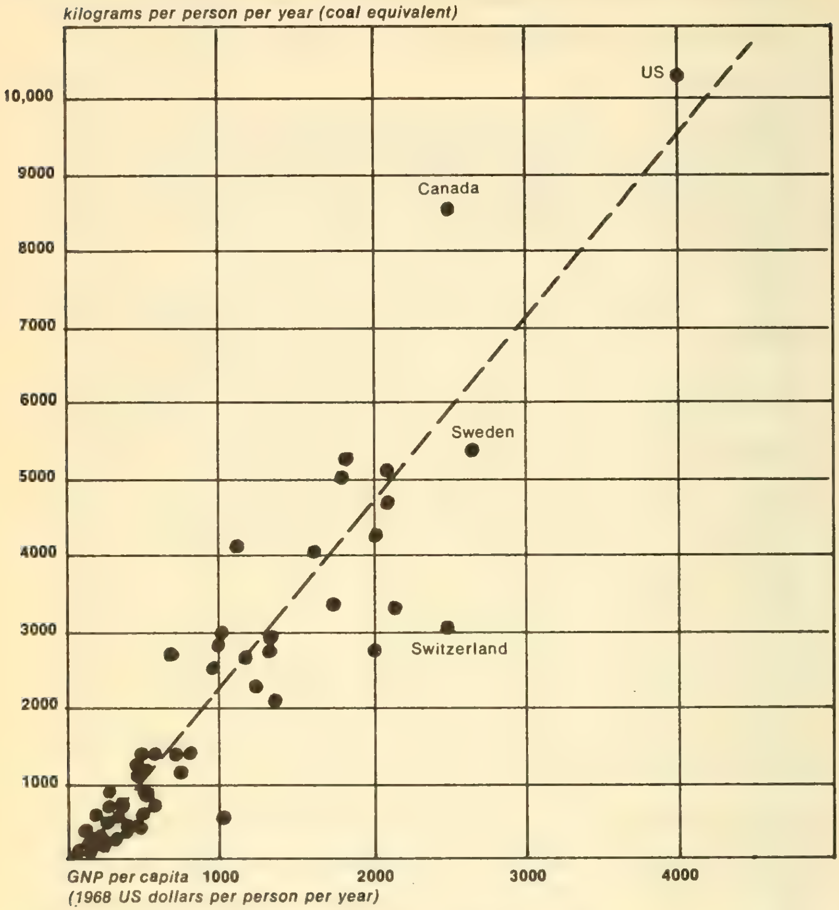
2. We have almost no knowledge about where the upper limits to these pollution growth curves might be.

3. The presence of natural delays in ecological processes increases the probability of underestimating the control measures necessary, and therefore of inadvertently reaching those upper limits.

4. Many pollutants are globally distributed; their harmful effects appear long distances from their points of generation.

It is not possible to illustrate each of these four points for each type of pollutant, both because of the space limitations

Figure 14 ENERGY CONSUMPTION AND GNP PER CAPITA



Although the nations of the world consume greatly varying amounts of energy per capita, energy consumption correlates fairly well with total output per capita (GNP per capita). The relationship is generally linear, with the scattering of points due to differences in climate, local fuel prices, and emphasis on heavy industry.

SOURCES: Energy consumption from UN Department of Economic and Social Affairs, *Statistical Yearbook 1969* (New York: United Nations, 1970). GNP per capita from *World Bank Atlas* (Washington, DC: International Bank for Reconstruction and Development, 1970).

of this book and because of the limitations of available data. Therefore we shall discuss each point using as examples those pollutants which have been most completely studied to date. It is not necessarily true that the pollutants mentioned here are the ones of greatest concern (although they are all of some concern). They are, rather, the ones we understand best.

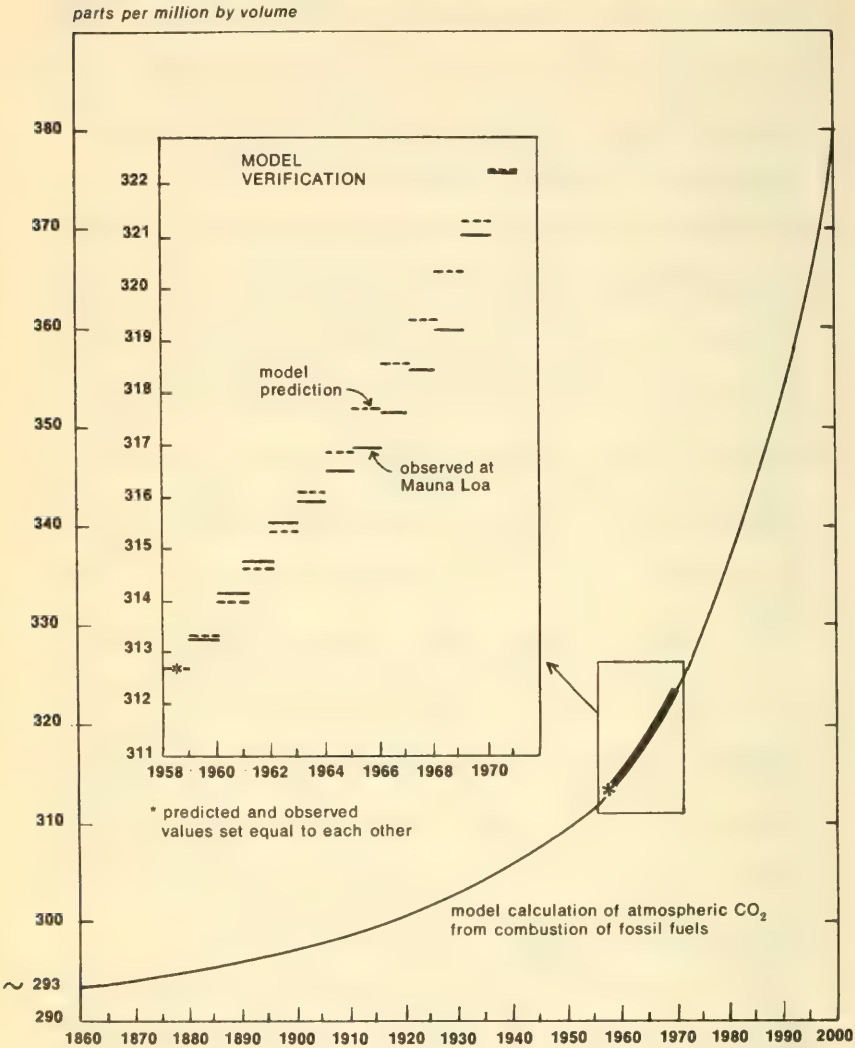
Exponentially increasing pollution

Virtually every pollutant that has been measured as a function of time appears to be increasing exponentially. The rates of increase of the various examples shown below vary greatly, but most are growing faster than the population. Some pollutants are obviously directly related to population growth (or agricultural activity, which is related to population growth). Others are more closely related to the growth of industry and advances in technology. Most pollutants in the complicated world system are influenced in some way by ***both*** the population and the industrialization positive feedback loops.

Let us begin by looking at the pollutants related to mankind's increasing use of energy. The process of economic development is in effect the process of utilizing more energy to increase the productivity and efficiency of human labor. In fact, one of the best indications of the wealth of a human population is the amount of energy it consumes per person (see figure 14). Per capita energy consumption in the world is increasing at a rate of 1.3 percent per year,[16] which means a total increase, including population growth, of 3.4 percent per year.

At present about 97 percent of mankind's industrial energy production comes from fossil fuels (coal, oil, and natural gas).[17] When these fuels are burned, they release, among other

Figure 15 CARBON DIOXIDE CONCENTRATION IN THE ATMOSPHERE



Atmospheric concentration of CO_2, observed since 1958 at Mauna Loa, Hawaii, has increased steadily. At present the increase averages about 1.5 part per million (ppm) each year. Calculations including the known exchanges of CO_2 between atmosphere, biosphere, and oceans predict that

the CO_2 concentration will reach 380 ppm by the year 2000, an increase of nearly 30 percent of the probable value in 1860. The source of this exponential increase in atmospheric CO_2 is man's increasing combustion of fossil fuels.

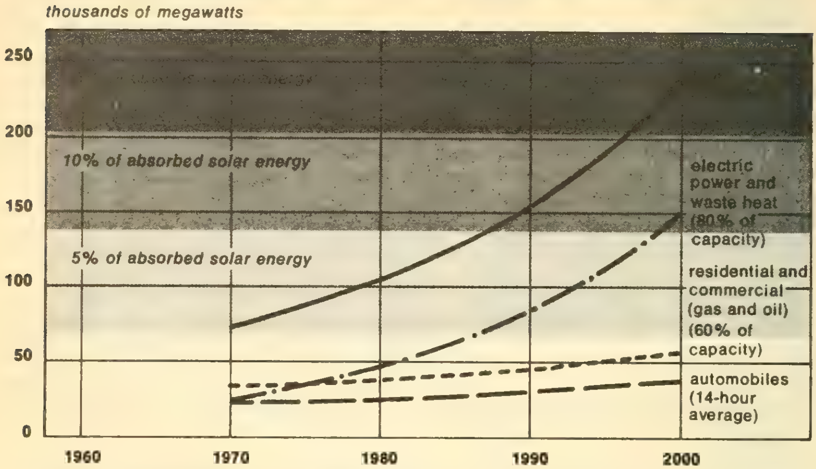
SOURCE: Lester Machta, "The Role of the Oceans and Biosphere in the Carbon Dioxide Cycle." Paper presented at Nobel Symposium 20 "The Changing Chemistry of the Oceans," Göteborg, Sweden, August 1971.

substances, carbon dioxide (CO_2) into the atmosphere. Currently about 20 billion tons of CO_2 are being released from fossil fuel combustion each year.[18] As figure 15 shows, the measured amount of CO_2 in the atmosphere is increasing exponentially, apparently at a rate of about 0.2 percent per year. Only about one half of the CO_2 released from burning fossil fuels has actually appeared in the atmosphere—the other half has apparently been absorbed, mainly by the surface water of the oceans.[19]

If man's energy needs are someday supplied by nuclear power instead of fossil fuels, this increase in atmospheric CO_2 will eventually cease, one hopes before it has had any measurable ecological or climatological effect.

There is, however, another side-effect of energy use, which is independent of the fuel source. By the laws of thermodynamics, essentially all of the energy used by man must ultimately be dissipated as heat. If the energy source is something other than incident solar energy (e.g., fossil fuels or atomic energy), that heat will result in warming the atmosphere, either directly, or indirectly through radiation from water used for cooling purposes. Locally, waste heat or "thermal pollution" in streams causes disruption in the balance of aquatic life.[20] Atmospheric waste heat around cities causes the formation of urban "heat islands," within which many meteorological anomalies occur.[21] Thermal pollution may have serious climatic effects, worldwide, when it reaches some appre-

Figure 16 WASTE HEAT GENERATION IN THE LOS ANGELES BASIN



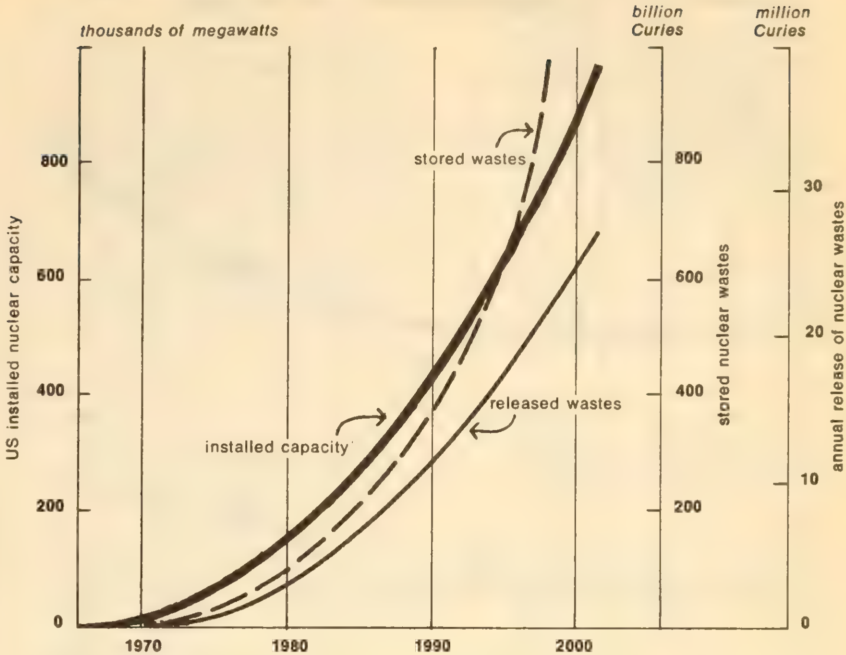
Waste heat released over the 4,000 square mile area of the Los Angeles basin currently amounts to about 5 percent of the total solar energy absorbed at the ground. At the present rate of growth, thermal release will reach 18 percent of incoming solar energy by the year 2000. This heat, the result of all energy generation and consumption processes, is already affecting the local climate.

SOURCE: L. Lees in *Man's Impact on the Global Environment,* Report of the Study of Critical Environmental Problems (Cambridge, Mass.: MIT Press, 1970).

ciable fraction of the energy normally absorbed by the earth from the sun.[22] In figure 16, the level of thermal pollution projected for one large city is shown as a fraction of incident solar energy.

Nuclear power will produce yet another kind of pollutant —radioactive wastes. Since nuclear power now provides only an insignificant fraction of the energy used by man, the possible environmental impact of the wastes released by nuclear reactors can only be surmised. Some idea may be gained, however, by the actual and expected releases of radioactive isotopes from the nuclear power plants being built today. A partial list of the expected annual discharge to the environment of a

Figure 17 NUCLEAR WASTES



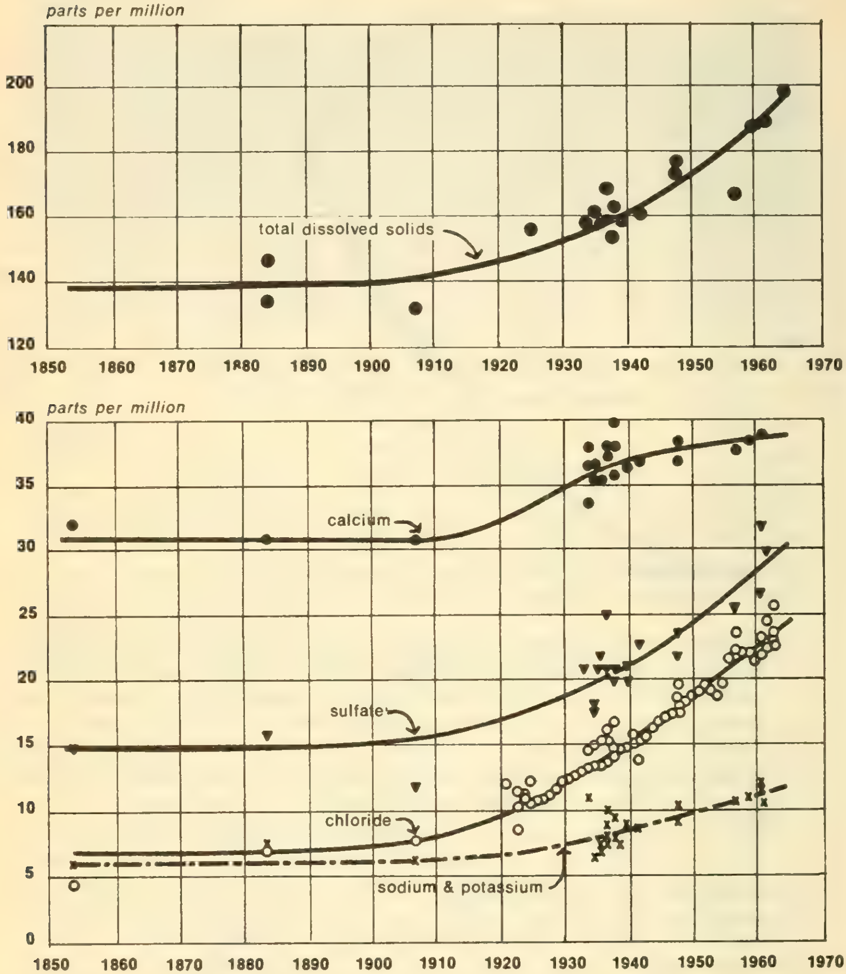
Installed nuclear generating capacity in the United States is expected to grow from 11 thousand megawatts in 1970 to more than 900 thousand megawatts in the year 2000. Total amount of stored nuclear wastes, radioactive by-products of the energy production, will probably exceed one thousand billion Curies by that year. Annual release of nuclear wastes, mostly in the form of krypton gas and tritium in cooling water, will reach 25 million Curies, if present release standards are still in effect.

SOURCES: Installed capacity to 1985 from US Atomic Energy Commission, *Forecast of Growth of Nuclear Power* (Washington, DC: Government Printing Office, 1971). Installed capacity to 2000 from Chauncey Starr, "Energy and Power," *Scientific American*, September 1971. Stored nuclear wastes from J. A. Snow, "Radioactive Waste from Reactors," *Scientist and Citizen* 9 (1967). Annual release of nuclear wastes calculated from specifications for 1.6 thousand megawatt plant in Calvert Cliffs, Maryland.

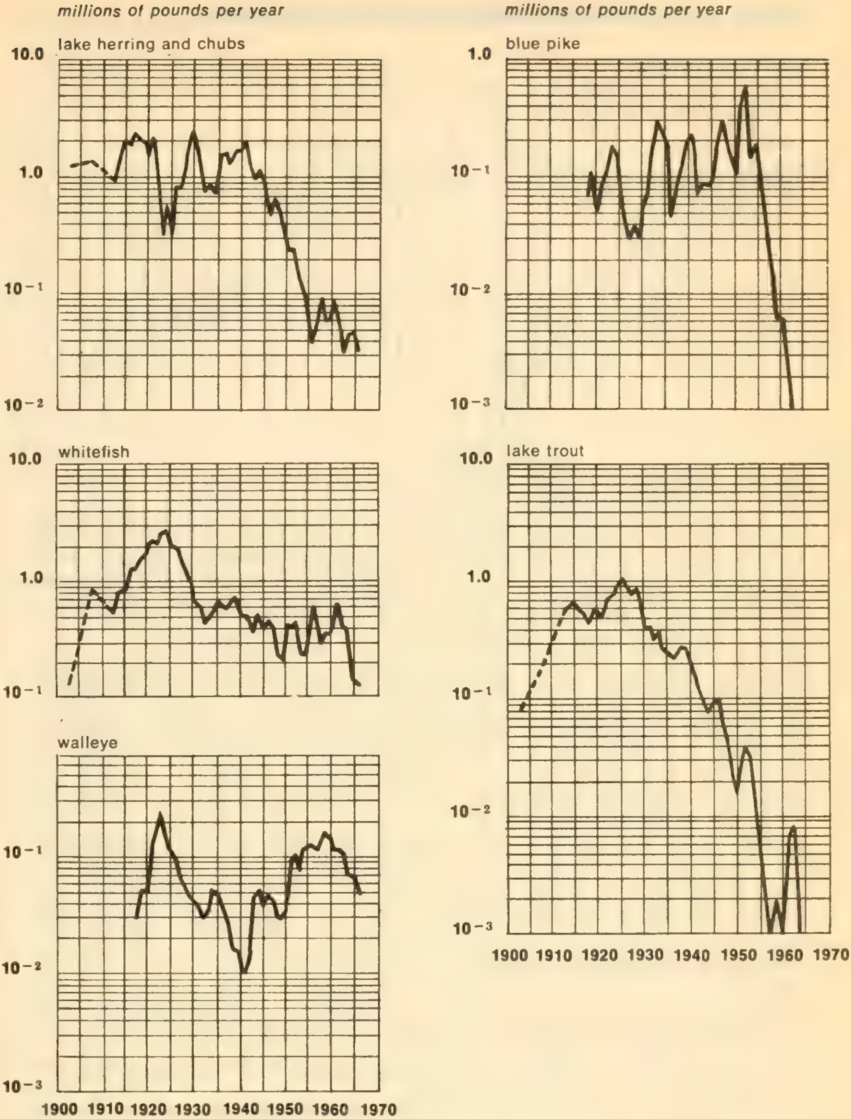
1.6 million kilowatt plant now under construction in the United States includes 42,800 Curies * of radioactive krypton

* A Curie is the radioactive equivalent of one gram of radium. This is such a large amount of radiation that environmental concentrations are usually expressed in microcuries (millionths of a Curie).

Figure 18 CHANGES IN CHEMICAL CHARACTERISTICS AND COMMERCIAL FISH PRODUCTION IN LAKE ONTARIO

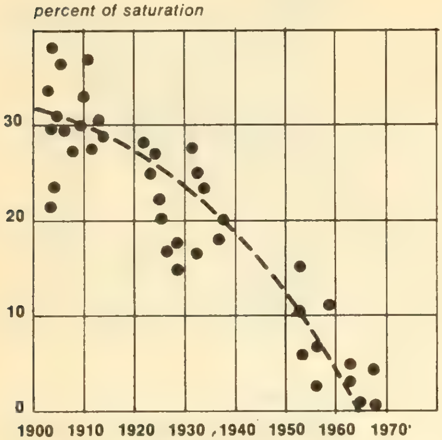


As a result of heavy dumping of municipal, industrial, and agricultural wastes into Lake Ontario, the concentrations of numerous salts have been rising exponentially. The chemical changes in the lake have resulted in severe declines in the catches of most commercially valuable fish. It should be noted that the plotting scale for fish catch is logarithmic, and thus the fish catch has decreased by factors of 100 to 1,000 for most species.



SOURCE: A. M. Beeton, *Statement on Pollution and Eutrophication of the Great Lakes*, The University of Wisconsin Center for Great Lakes Studies Special Report #11 (Milwaukee, Wisc.: University of Wisconsin, 1970).

Figure 19 OXYGEN CONTENT OF THE BALTIC SEA



Increasing accumulation of organic wastes in the Baltic Sea, where water circulation is minimal, has resulted in a steadily decreasing oxygen concentration in the water. In some areas, especially in deeper waters, oxygen concentration is zero and almost no forms of aquatic life can be supported.

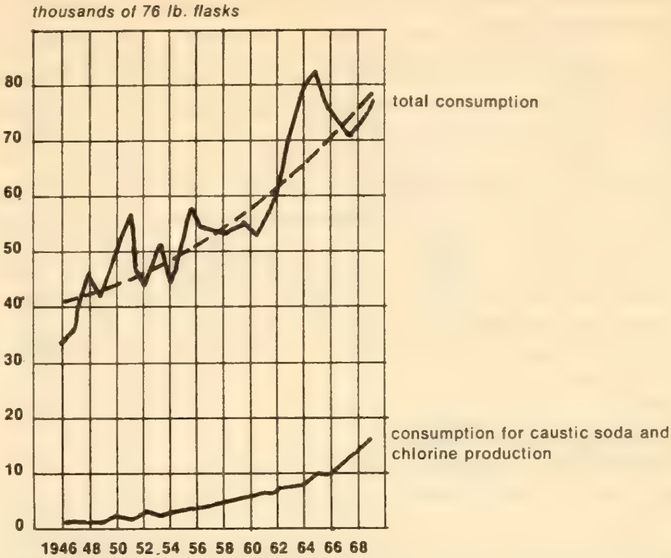
SOURCE: Stig H. Fonselius, "Stagnant Sea," *Environment*, July/August 1970.

(half-life ranging from a few hours to 9.4 years, depending on the isotope) in the stack gases, and 2,910 Curies of tritium (half-life 12.5 years) in the waste water.[23] Figure 17 shows how the nuclear generating capacity of the United States is expected to grow from now until the year 2000. The graph also includes an estimate of radioactive wastes annually released by these nuclear power plants and of accumulated wastes (from spent reactor fuels) that will have to be safely stored.

Carbon dioxide, thermal energy, and radioactive wastes are just three of the many disturbances man is inserting into the environment at an exponentially increasing rate. Other examples are shown in figures 18–21.

Figure 18 shows the chemical changes occurring in a large North American lake from accumulation of soluble industrial,

Figure 20 US MERCURY CONSUMPTION



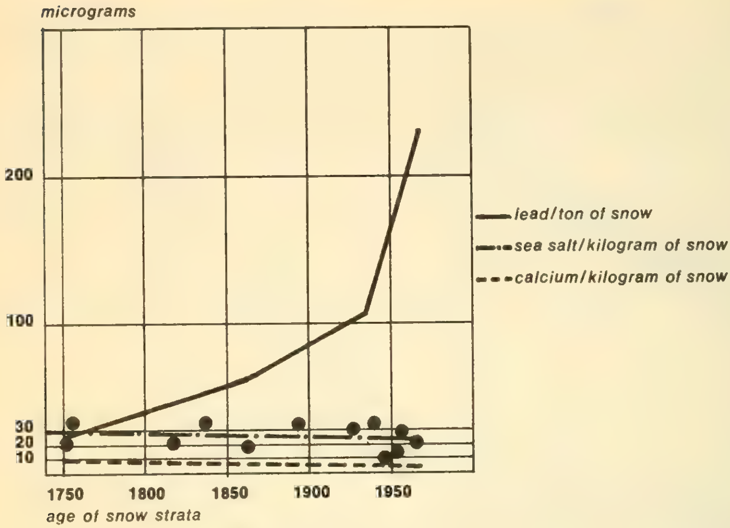
Mercury consumption in the United States shows an exponential trend, on which short-term market fluctuations are superimposed. A large part of the mercury is used for the production of caustic soda and chlorine. The chart does not include the rising amount of mercury released into the atmosphere from the combustion of fossil fuels.

SOURCE: Barry Commoner, Michael Carr, and Paul J. Stamler, "The Causes of Pollution," *Environment*, April 1971.

agricultural, and municipal wastes. The accompanying decrease in commercial fish production from the lake is also indicated. Figure 19 illustrates why the increase in organic wastes has such a catastrophic effect on fish life. The figure shows the amount of dissolved oxygen (which fish "breathe") in the Baltic Sea as a function of time. As increasing amounts of wastes enter the water and decay, the dissolved oxygen is depleted. In the case of some parts of the Baltic, the oxygen level has actually reached zero.

The toxic metals lead and mercury are released into waterways and into the atmosphere from automobiles, incinerators,

Figure 21 LEAD IN THE GREENLAND ICE CAP



Deep samples of snow from the Greenland Ice Sheet show increasingly high deposits of lead over time. Concentrations of calcium and sea salt were also measured as a control. Presence of lead reflects increasing world industrial use of the metal, including direct release into the atmosphere from automobile exhausts.

SOURCE: C. C. Patterson and J. D. Salvia, "Lead in the Modern Environment—How Much is Natural?" *Scientist and Citizen,* April 1968.

industrial processes, and agricultural pesticides. Figure 20 shows the exponential increase in mercury consumption in the United States from 1946 to 1968. Only 18 percent of this mercury is captured and recycled after use.[24] An exponential increase in deposits of airborne lead has been detected by extraction of successively deeper samples from the Greenland ice cap, as shown in figure 21.

Unknown upper limits

All of these exponential curves of various kinds of pollution can be extrapolated into the future, as we have extrapolated land needs in figure 10 and resource use in figure 11. In both of

these previous figures, the exponential growth curve eventually reached an upper limit—the total amount of arable land or of resources economically available in the earth. However, no upper bounds have been indicated for the exponential growth curves of pollutants in figures 15–21, because it is not known how much we can perturb the natural ecological balance of the earth without serious consequences. It is not known how much CO_2 or thermal pollution can be released without causing irreversible changes in the earth's climate, or how much radioactivity, lead, mercury, or pesticide can be absorbed by plants, fish, or human beings before the vital processes are severely interrupted.

Natural delays in ecological processes

This ignorance about the limits of the earth's ability to absorb pollutants should be reason enough for caution in the release of polluting substances. The danger of reaching those limits is especially great because there is typically a long delay between the release of a pollutant into the environment and the appearance of its negative effect on the ecosystem. The dynamic implications of such a delayed effect can be illustrated by the path of DDT through the environment after its use as an insecticide. The results presented below are taken from a detailed System Dynamics study* using the numerical constants appropriate to DDT. The general conclusion is applicable (with some change in the exact numbers involved) to all long-lived toxic substances, such as mercury, lead, cadmium, other pesticides, polychlorobiphenyl (PCB), and radioactive wastes.

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* The study, by Jørgen Randers and Dennis L. Meadows, is listed in the appendix.

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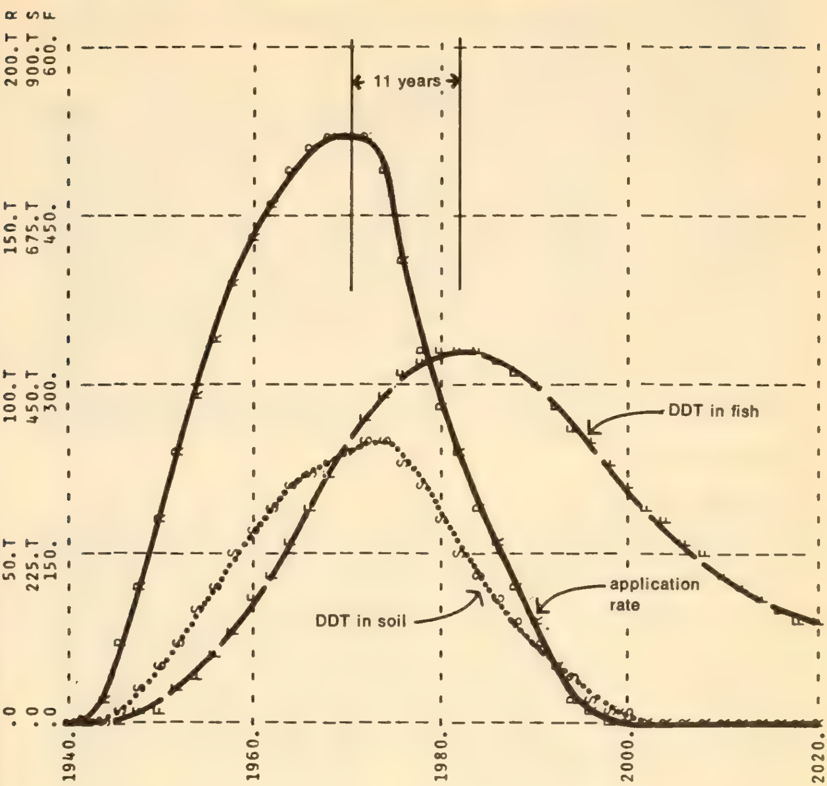
DDT is a man-made organic chemical released into the environment as a pesticide at a rate of about 100,000 tons annually.[25] After its application by spraying, part of it evaporates and is carried long distances in the air before it eventually precipitates back onto the land or into the ocean. In the ocean some of the DDT is taken up by plankton, some of the plankton are eaten by fish, and some of the fish are finally eaten by man. At each step in the process the DDT may be degraded into harmless substances, it may be released back into the ocean, or it may be concentrated in the tissues of living organisms. There is some time delay involved at each of these steps. All these possible pathways have been analyzed by a computer to produce the results seen in figure 22.

The DDT application rate shown in the figure follows the world application rate from 1940 to 1970. The graph shows what would happen if in 1970 the world DDT application rate began to decrease gradually until it reached zero in the year 2000. Because of the inherent delays in the system, the level of DDT in fish continues to rise for more than 10 years after DDT use starts declining, and the level in fish *does not come back down to the 1970 level until the year 1995*—more than two decades after the decision is made to reduce DDT application.

Whenever there is a long delay from the time of release of a pollutant to the time of its appearance in a harmful form, we know there will be an equally long delay from the time of *control* of that pollutant to the time when its harmful effect finally decreases. In other words, any pollution control system based on instituting controls only when some harm is already detected will probably guarantee that the problem will get much worse before it gets better. Systems of this sort are

Figure 22 DDT FLOWS IN THE ENVIRONMENT



Calculation of the path of DDT through the environment shows the probable result if the world DDT application rate began to decline in 1970. The application rate shown is historically correct to 1970. DDT in soil peaks shortly after the application rate begins to decline, but DDT in fish continues to rise for 11 years and does not fall back to its 1970 level until 1995. DDT in fish-eating animals, such as birds and man, would show an even longer delay in responding to the decrease in application rate.

SOURCE: Jørgen Randers and Dennis L. Meadows, "System Simulation to Test Environmental Policy I: A Sample Study of DDT Movement in the Environment" (Cambridge, Mass.: Massachusetts Institute of Technology, 1971).

exceedingly difficult to control, because they require that present actions be based on results expected far in the future.

Global distribution of pollutants

At the present time only the developed nations of the world are seriously concerned about pollution. It is an unfortunate characteristic of many types of pollution, however, that eventually they become widely distributed around the world. Although Greenland is far removed from any source of atmospheric lead pollution, the amount of lead deposited in Greenland ice has increased 300 percent yearly since 1940.[26] DDT has accumulated in the body fat of humans in every part of the globe, from Alaskan eskimos to city-dwellers of New Delhi, as shown in table 5.

Pollution Limits

Since pollution generation is a complicated function of population, industrialization, and specific technological developments, it is difficult to estimate exactly how fast the exponential curve of total pollution release is rising. We might estimate that if the 7 billion people of the year 2000 have a GNP per capita as high as that of present-day Americans, the total pollution load on the environment would be at least ten times its present value. Can the earth's natural systems support an intrusion of that magnitude? We have no idea. Some people believe that man has already so degraded the environment that irreversible damage has been done to large natural systems. We do not know the precise upper limit of the earth's ability to absorb any single kind of pollution, much less its ability to absorb the combination of all kinds of pollution. We do know however that there *is* an upper limit. It has already been surpassed in many local environments. The surest way to

Table 5 DDT IN BODY FAT

Population	*Year*	*Number in sample*	*Concentration of DDT and toxic breakdown products in body fat (parts per million)*
Alaska (Eskimos)	1960	20	3.0
Canada	1959–60	62	4.9
England	1961–62	131	2.2
England	1964	100	3.9
France	1961	10	5.2
Germany	1958–59	60	2.3
Hungary	1960	48	12.4
India (Delhi)	1964	67	26.0
Israel	1963–64	254	19.2
United States (Kentucky)	1942	10	.0
United States (Georgia, Kentucky, Arizona, Washington)	1961–62	130	12.7
United States (all areas)	1964	64	7.6

SOURCE: Wayland J. Hayes, Jr., "Monitoring Food and People for Pesticide Content," in *Scientific Aspects of Pest Control* (Washington, DC: National Academy of Sciences—National Research Council, 1966).

reach that upper limit globally is to increase exponentially both the number of people and the polluting activities of each person.

The trade-offs involved in the environmental sector of the world system are every bit as difficult to resolve as those in the agricultural and natural resource sectors. The benefits of pollution-generating activities are usually far removed in both space and time from the costs. To make equitable decisions, therefore, one must consider both space and time factors. If wastes are dumped upstream, who will suffer downstream? If fungicides containing mercury are used now, to what extent,

when, and where will the mercury appear in ocean fish? If polluting factories are located in remote areas to "isolate" the pollutants, where will those pollutants be ten or twenty years from now?

It may be that technological developments will allow the expansion of industry with decreasing pollution, but only at a high cost. The US Council on Environmental Quality has called for an expenditure of $105 billion between now and 1975 (42 percent of which is to be paid by industry) for just a partial cleanup of American air, water, and solid-waste pollution.[27] Any country can postpone the payment of such costs to increase the present growth rate of its capital plant, but only at the expense of future environmental degradation, which may be reversible only at very high cost.

A FINITE WORLD

We have mentioned many difficult trade-offs in this chapter in the production of food, in the consumption of resources, and in the generation and clean-up of pollution. By now it should be clear that all of these trade-offs arise from one simple fact—the earth is finite. The closer any human activity comes to the limit of the earth's ability to support that activity, the more apparent and unresolvable the trade-offs become. When there is plenty of unused arable land, there can be more people and also more food per person. When all the land is already used, the trade-off between more people or more food per person becomes a choice between absolutes.

In general, modern society has not learned to recognize and deal with these trade-offs. The apparent goal of the present world system is to produce more people with more (food, material goods, clean air and water) for each person. In this

chapter we have noted that if society continues to strive for that goal, it will eventually reach one of many earthly limitations. As we shall see in the next chapter, it is not possible to foretell exactly which limitation will occur first or what the consequences will be, because there are many conceivable, unpredictable human responses to such a situation. It is possible, however, to investigate what conditions and what changes in the world system might lead society to collision with or accommodation to the limits to growth in a finite world.

CHAPTER V

THE STATE OF GLOBAL EQUILIBRIUM

Most persons think that a state in order to be happy ought to be large; but even if they are right, they have no idea of what is a large and what a small state. . . . To the size of states there is a limit, as there is to other things, plants, animals, implements; for none of these retain their natural power when they are too large or too small, but they either wholly lose their nature, or are spoiled.

ARISTOTLE, 322 B.C.

We have seen that positive feedback loops operating without any constraints generate exponential growth. In the world system two positive feedback loops are dominant now, producing exponential growth of population and of industrial capital.

In any finite system there must be constraints that can act to stop exponential growth. These constraints are negative feedback loops. The negative loops become stronger and stronger as growth approaches the ultimate limit, or carrying capacity, of the system's environment. Finally the negative loops balance or dominate the positive ones, and growth comes

to an end. In the world system the negative feedback loops involve such processes as pollution of the environment, depletion of nonrenewable resources, and famine.

The delays inherent in the action of these negative loops tend to allow population and capital to overshoot their ultimately sustainable levels. The period of overshoot is wasteful of resources. It generally decreases the carrying capacity of the environment as well, intensifying the eventual decline in population and capital.

The growth-stopping pressures from negative feedback loops are already being felt in many parts of human society. The major societal responses to these pressures have been directed at the negative feedback loops themselves. Technological solutions, such as those discussed in chapter IV, have been devised to weaken the loops or to disguise the pressures they generate so that growth can continue. Such means may have some short-term effect in relieving pressures caused by growth, but in the long run they do nothing to prevent the overshoot and subsequent collapse of the system.

Another response to the problems created by growth would be to weaken the *positive* feedback loops that are generating the growth. Such a solution has almost never been acknowledged as legitimate by any modern society, and it has certainly never been effectively carried out. What kinds of policies would such a solution involve? What sort of world would result? There is almost no historical precedent for such an approach, and thus there is no alternative but to discuss it in terms of models—either mental models or formal, written models. How will the world model behave if we include in it some policy to control growth deliberately? Will such a policy change generate a "better" behavior mode?

Whenever we use words such as "better" and begin choosing among alternative model outputs, we, the experimenters, are inserting our own values and preferences into the modeling process. The values built into each causal relationship of the model are the real, operational values of the world to the degree that we can determine them. The values that cause us to rank computer outputs as "better" or "worse" are the personal values of the modeler or his audience. We have already asserted our own value system by rejecting the overshoot and collapse mode as undesirable. Now that we are seeking a "better" result, we must define our goal for the system as clearly as possible. We are searching for a model output that represents a world system that is:

1. sustainable without sudden and uncontrollable collapse; and

2. capable of satisfying the basic material requirements of all of its people.

Now let us see what policies will bring about such behavior in the world model.

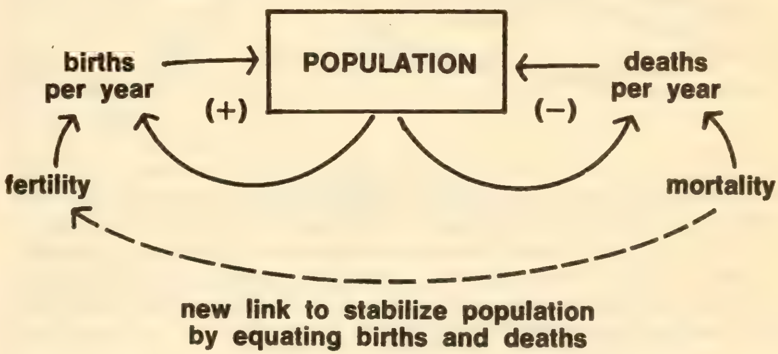
DELIBERATE CONSTRAINTS ON GROWTH

You will recall that the positive feedback loop generating population growth involves the birth rate and all the socio-economic factors that influence the birth rate. It is counteracted by the negative loop of the death rate.

The overwhelming growth in world population caused by the positive birth-rate loop is a recent phenomenon, a result of mankind's very successful reduction of worldwide mortality. The controlling negative feedback loop has been weakened, allowing the positive loop to operate virtually without constraint. There are only two ways to restore the resulting im-

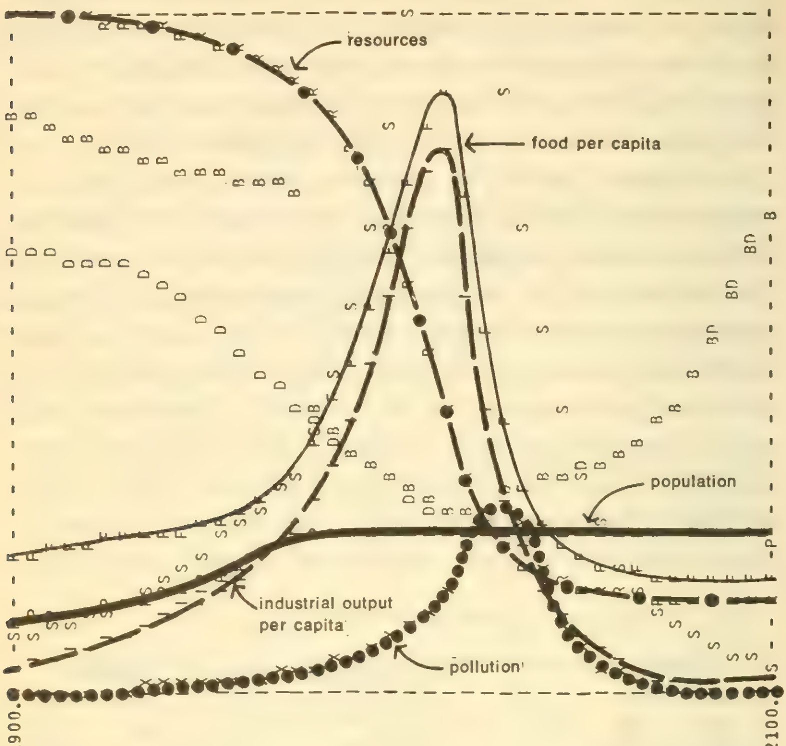
balance. Either the birth rate must be brought down to equal the new, lower death rate, or the death rate must rise again. All of the "natural" constraints to population growth operate in the second way—they raise the death rate. Any society wishing to avoid that result must take deliberate action to control the positive feedback loop—to reduce the birth rate.

In a dynamic model it is a simple matter to counteract runaway positive feedback loops. For the moment let us suspend the requirement of political feasibility and use the model to test the physical, if not the social, implications of limiting population growth. We need only add to the model one more causal loop, connecting the birth rate and the death rate. In other words, we require that the number of babies born each year be equal to the expected number of deaths in the population that year. Thus the positive and negative feedback loops are exactly balanced. As the death rate decreases, because of better food and medical care, the birth rate will decrease



simultaneously. Such a requirement, which is as mathematically simple as it is socially complicated, is for our purposes an experimental device, not necessarily a political recommen-

Figure 44 WORLD MODEL WITH STABILIZED POPULATION



In this computer run conditions in the model system are identical to those in the standard run (figure 35), except that population is held constant after 1975 by equating the birth rate with the death rate. The remaining unrestricted positive feedback loop in the system, involving industrial capital, continues to generate exponential growth of industrial output, food, and services per capita Eventual depletion of nonrenewable resources brings a sudden collapse of the industrial system.

dation.* The result of inserting this policy into the model in 1975 is shown in figure 44.

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* This suggestion for stabilizing population was originally proposed by Kenneth E. Boulding in *The Meaning of the 20th Century* (New York: Harper and Row, 1964).

In figure 44 the positive feedback loop of population growth is effectively balanced, and population remains constant. At first the birth and death rates are low. But there is still one unchecked positive feedback loop operating in the model—the one governing the growth of industrial capital. The gain around that loop increases when population is stabilized, resulting in a very rapid growth of income, food, and services per capita. That growth is soon stopped, however, by depletion of nonrenewable resources. The death rate then rises, but total population does not decline because of our requirement that birth rate equal death rate (clearly unrealistic here).

Apparently, if we want a stable system, it is not desirable to let even one of the two critical positive feedback loops generate uncontrolled growth. Stabilizing population alone is not sufficient to prevent overshoot and collapse; a similar run with constant capital and rising population shows that stabilizing capital alone is also not sufficient. What happens if we bring *both* positive feedback loops under control simultaneously? We can stabilize the capital stock in the model by requiring that the investment rate equal the depreciation rate, with an additional model link exactly analogous to the population-stabilizing one.

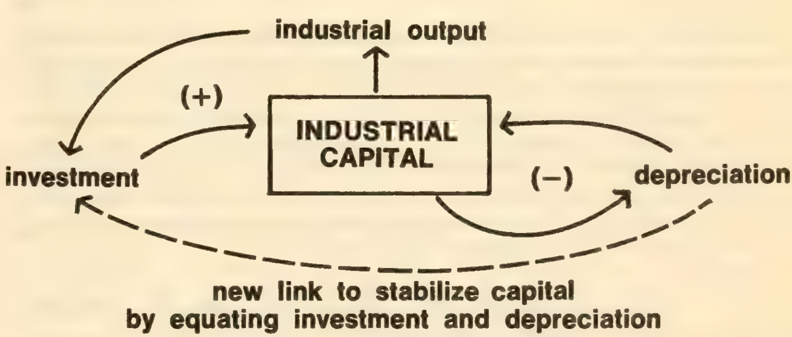
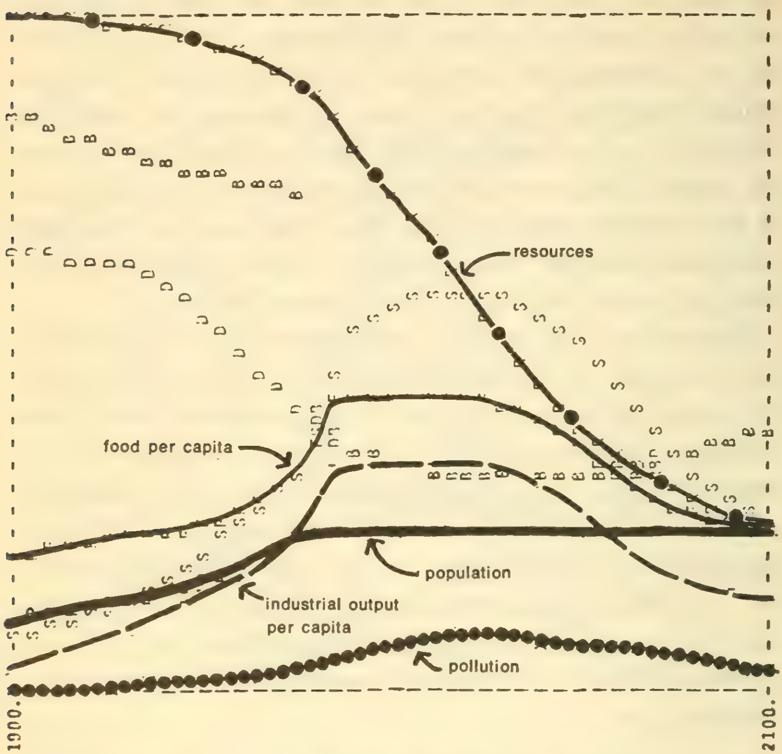


Figure 45 WORLD MODEL WITH STABILIZED POPULATION AND CAPITAL



Restriction of capital growth, by requiring that capital investment equal depreciation, is added to the population stabilization policy of figure 44. Now that exponential growth is halted, a temporary stable state is attained. Levels of population and capital in this state are sufficiently high to deplete resources rapidly, however, since no resource-conserving technologies have been assumed. As the resource base declines, industrial output decreases. Although the capital base is maintained at the same level, efficiency of capital goes down since more capital must be devoted to obtaining resources than to producing usable output.

The result of stopping population growth in 1975 and industrial capital growth in 1985 with no other changes is shown in figure 45. (Capital was allowed to grow until 1985 to raise slightly the average material standard of living.) In this run

the severe overshoot and collapse of figure 44 are prevented. Population and capital reach constant values at a relatively high level of food, industrial output, and services per person. Eventually, however, resource shortages reduce industrial output and the temporarily stable state degenerates.

What model assumptions will give us a combination of a decent living standard with somewhat greater stability than that attained in figure 45? We can improve the model behavior greatly by combining technological changes with value changes that reduce the growth tendencies of the system. Different combinations of such policies give us a series of computer outputs that represent a system with reasonably high values of industrial output per capita and with long-term stability. One example of such an output is shown in figure 46.

The policies that produced the behavior shown in figure 46 are:

1. Population is stabilized by setting the birth rate equal to the death rate in 1975. Industrial capital is allowed to increase naturally until 1990, after which it, too, is stabilized, by setting the investment rate equal to the depreciation rate.

2. To avoid a nonrenewable resource shortage such as that shown in figure 45, resource consumption per unit of industrial output is reduced to one-fourth of its 1970 value. (This and the following five policies are introduced in 1975.)

3. To further reduce resource depletion and pollution, the economic preferences of society are shifted more toward services such as education and health facilities and less toward factory-produced material goods. (This change is made through the relationship giving "indicated" or "desired" services per capita as a function of rising income.)

4. Pollution generation per unit of industrial and agricultural output is reduced to one-fourth of its 1970 value.

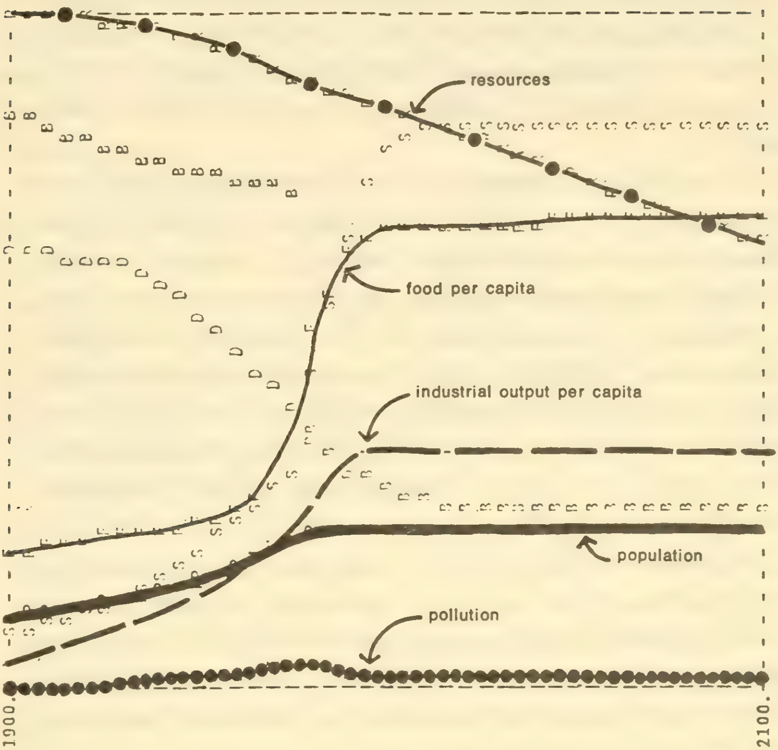
5. Since the above policies alone would result in a rather low value of food per capita, some people would still be malnourished if the traditional inequalities of distribution persist. To avoid this situation, high value is placed on producing sufficient food for *all* people. Capital is therefore diverted to food production even if such an investment would be considered "uneconomic." (This change is carried out through the "indicated" food per capita relationship.)

6. This emphasis on highly capitalized agriculture, while necessary to produce enough food, would lead to rapid soil erosion and depletion of soil fertility, destroying long-term stability in the agricultural sector. Therefore the use of agricultural capital has been altered to make soil enrichment and preservation a high priority. This policy implies, for example, use of capital to compost urban organic wastes and return them to the land (a practice that also reduces pollution).

7. The drains on industrial capital for higher services and food production and for resource recycling and pollution control under the above six conditions would lead to a low final level of industrial capital stock. To counteract this effect, the average lifetime of industrial capital is increased, implying better design for durability and repair and less discarding because of obsolescence. This policy also tends to reduce resource depletion and pollution.

In figure 46 the stable world population is only slightly larger than the population today. There is more than twice as much food per person as the average value in 1970, and world average lifetime is nearly 70 years. The average indus-

Figure 46 STABILIZED WORLD MODEL I



Technological policies are added to the growth-regulating policies of the previous run to produce an equilibrium state sustainable far into the future. Technological policies include resource recycling, pollution control devices, increased lifetime of all forms of capital, and methods to restore eroded and infertile soil. Value changes include increased emphasis on food and services rather than on industrial production. As in figure 45, births are set equal to deaths and industrial capital investment equal to capital depreciation. Equilibrium value of industrial output per capita is three times the 1970 world average.

trial output per capita is well above today's level, and services per capita have tripled. Total average income per capita (industrial output, food, and services combined) is about $1,800. This value is about half the present average US income, equal to

the present average European income, and three times the present average world income. Resources are still being gradually depleted, as they must be under any realistic assumption, but the rate of depletion is so slow that there is time for technology and industry to adjust to changes in resource availability.

The numerical constants that characterize this model run are not the only ones that would produce a stable system. Other people or societies might resolve the various trade-offs differently, putting more or less emphasis on services or food or pollution or material income. This example is included merely as an illustration of the levels of population and capital that are *physically maintainable* on the earth, under the most optimistic assumptions. The model cannot tell us how to attain these levels. It can only indicate a set of mutually consistent goals that are attainable.

Now let us go back at least in the general direction of the real world and relax our most unrealistic assumptions—that we can suddenly and absolutely stabilize population and capital. Suppose we retain the last six of the seven policy changes that produced figure 46, but replace the first policy, beginning in 1975, with the following:

1. The population has access to 100 percent effective birth control.

2. The average desired family size is two children.

3. The economic system endeavors to maintain average industrial output per capita at about the 1975 level. Excess industrial capability is employed for producing consumption goods rather than increasing the industrial capital investment rate above the depreciation rate.

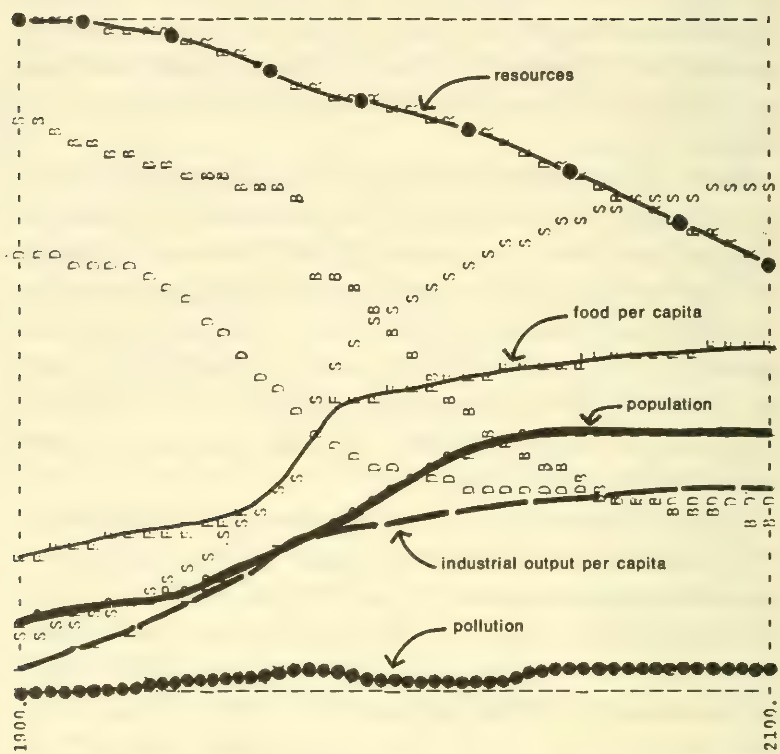
The model behavior that results from this change is shown in figure 47. Now the delays in the system allow population to grow much larger than it did in figure 46. As a consequence, material goods, food, and services per capita remain lower than in previous runs (but still higher than they are on a world average today).

We do not suppose that any single one of the policies necessary to attain system stability in the model can or should be suddenly introduced in the world by 1975. A society choosing stability as a goal certainly must approach that goal gradually. It is important to realize, however, that the longer exponential growth is allowed to continue, the fewer possibilities remain for the final stable state. Figure 48 shows the result of waiting until the year 2000 to institute the same policies that were instituted in 1975 in figure 47.

In figure 48 both population and industrial output per capita reach much higher values than in figure 47. As a result pollution builds to a higher level and resources are severely depleted, in spite of the resource-saving policies finally introduced. In fact, during the 25-year delay (from 1975 to 2000) in instituting the stabilizing policies, resource consumption is about equal to the total 125-year consumption from 1975 to 2100 of figure 47.

Many people will think that the changes we have introduced into the model to avoid the growth-and-collapse behavior mode are not only impossible, but unpleasant, dangerous, even disastrous in themselves. Such policies as reducing the birth rate and diverting capital from production of material goods, by whatever means they might be implemented, seem unnatural and unimaginable, because they have not, in most people's experience, been tried, or even seriously suggested. Indeed there

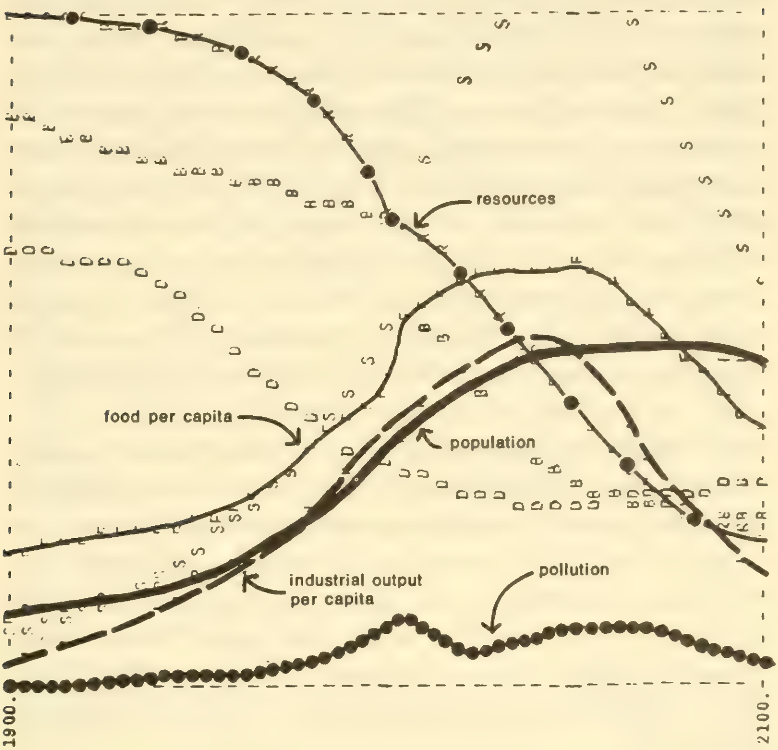
Figure 47 STABILIZED WORLD MODEL II



If the strict restrictions on growth of the previous run are removed, and population and capital are regulated within the natural delays of the system, the equilibrium level of population is higher and the level of industrial output per capita is lower than in figure 46. Here it is assumed that perfectly effective birth control and an average desired family size of two children are achieved by 1975. The birth rate only slowly approaches the death rate because of delays inherent in the age structure of the population.

would be little point even in discussing such fundamental changes in the functioning of modern society if we felt that the present pattern of unrestricted growth were sustainable into the future. All the evidence available to us, however, suggests that of the three alternatives—unrestricted growth, a self-

Figure 48 WORLD MODEL WITH STABILIZING POLICIES INTRODUCED IN THE YEAR 2000



If all the policies instituted in 1975 in the previous figure are delayed until the year 2000, the equilibrium state is no longer sustainable. Population and industrial capital reach levels high enough to create food and resource shortages before the year 2100.

imposed limitation to growth, or a nature-imposed limitation to growth—only the last two are actually possible.

Accepting the nature-imposed limits to growth requires no more effort than letting things take their course and waiting to see what will happen. The most probable result of that decision, as we have tried to show here, will be an uncontrollable decrease in population and capital. The real meaning of such a

collapse is difficult to imagine because it might take so many different forms. It might occur at different times in different parts of the world, or it might be worldwide. It could be sudden or gradual. If the limit first reached were that of food production, the nonindustrialized countries would suffer the major population decrease. If the first limit were imposed by exhaustion of nonrenewable resources, the industrialized countries would be most affected. It might be that the collapse would leave the earth with its carrying capacity for animal and plant life undiminished, or it might be that the carrying capacity would be reduced or destroyed. Certainly whatever fraction of the human population remained at the end of the process would have very little left with which to build a new society in any form we can now envision.

Achieving a self-imposed limitation to growth would require much effort. It would involve learning to do many things in new ways. It would tax the ingenuity, the flexibility, and the self-discipline of the human race. Bringing a deliberate, controlled end to growth is a tremendous challenge, not easily met. Would the final result be worth the effort? What would humanity gain by such a transition, and what would it lose? Let us consider in more detail what a world of nongrowth might be like.

THE EQUILIBRIUM STATE

We are by no means the first people in man's written history to propose some sort of nongrowing state for human society. A number of philosophers, economists, and biologists have discussed such a state and called it by many different names, with as many different meanings.*

We have, after much discussion, decided to call the state of

constant population and capital, shown in figures 46 and 47, by the term "equilibrium." Equilibrium means a state of balance or equality between opposing forces. In the dynamic terms of the world model, the opposing forces are those causing population and capital stock to increase (high desired family size, low birth control effectiveness, high rate of capital investment) and those causing population and capital stock to decrease (lack of food, pollution, high rate of depreciation or obsolescence). The word "capital" should be understood to mean service, industrial, and agricultural capital combined. *Thus the most basic definition of the state of global equilibrium is that population and capital are essentially stable, with the forces tending to increase or decrease them in a carefully controlled balance.*

There is much room for variation within that definition. We have only specified that the stocks of capital and population remain constant, but they might theoretically be constant

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* See, for instance:

Plato, *Laws,* 350 B.C.

Aristotle, *Politics,* 322 B.C.

Thomas Robert Malthus, *An Essay on the Principle of Population,* 1798.

John Stuart Mill, *Principles of Political Economy,* 1857.

Harrison Brown, *The Challenge of Man's Future* (New York: Viking Press, 1954).

Kenneth E. Boulding, "The Economics of the Coming Spaceship Earth," in *Environmental Quality in a Growing Economy,* ed. H. Jarrett (Baltimore, Md.: Johns Hopkins Press, 1966).

E. J. Mishan, *The Costs of Economic Growth* (New York: Frederick A. Praeger, 1967).

Herman E. Daly, "Toward a Stationary-State Economy," in *The Patient Earth,* ed. J. Harte and Robert Socolow (New York: Holt, Rinehart, and Winston, 1971).

at a high level or a low level—or one might be high and the other low. A tank of water can be maintained at a given level with a fast inflow and outflow of water or with a slow trickle in and out. If the flow is fast, the average drop of water will spend less time in the tank than if the flow is slow. Similarly, a stable population of any size can be achieved with either high, equal birth and death rates (short average lifetime) or low, equal birth and death rates (long average lifetime). A stock of capital can be maintained with high investment and depreciation rates or low investment and depreciation rates. Any combination of these possibilities would fit into our basic definition of global equilibrium.

What criteria can be used to choose among the many options available in the equilibrium state? The dynamic interactions in the world system indicate that the first decision that must be made concerns time. *How long should the equilibrium state exist?* If society is only interested in a time span of 6 months or a year, the world model indicates that almost any level of population and capital could be maintained. If the time horizon is extended to 20 or 50 years, the options are greatly reduced, since the rates and levels must be adjusted to ensure that the capital investment rate will not be limited by resource availability during that time span, or that the death rate will not be uncontrollably influenced by pollution or food shortage. The longer a society prefers to maintain the state of equilibrium, the lower the rates and levels must be.

At the limit, of course, no population or capital level can be maintained forever, but that limit is very far away in time if resources are managed wisely and if there is a sufficiently long time horizon in planning. Let us take as a reasonable time horizon the expected lifetime of a child born into the

world tomorrow—70 years if proper food and medical care are supplied. Since most people spend a large part of their time and energy raising children, they might choose as a minimum goal that the society left to those children can be maintained for the full span of the children's lives.

If society's time horizon is as long as 70 years, the permissible population and capital levels may not be too different from those existing today, as indicated by the equilibrium run in figure 47 (which is, of course, only one of several possibilities). The rates would be considerably different from those of today, however. Any society would undoubtedly prefer that the death rate be low rather than high, since a long, healthy life seems to be a universal human desire. To maintain equilibrium with long life expectancy, the birth rate then must also be low. It would be best, too, if the capital investment and depreciation rates were low, because the lower they are, the less resource depletion and pollution there will be. Keeping depletion and pollution to a minimum could either increase the maximum size of the population and capital levels or increase the length of time the equilibrium state could be maintained, depending on which goal the society as a whole preferred.

By choosing a fairly long time horizon for its existence, and a long average lifetime as a desirable goal, we have now arrived at a minimum set of requirements for the state of global equilibrium. They are:

1. *The capital plant and the population are constant in size.* The birth rate equals the death rate and the capital investment rate equals the depreciation rate.

2. *All input and output rates—births, deaths, investment, and depreciation—are kept to a minimum.*

3. *The levels of capital and population and the ratio of the two are set in accordance with the values of the society.* They may be deliberately revised and slowly adjusted as the advance of technology creates new options.

An equilibrium defined in this way does not mean stagnation. Within the first two guidelines above, corporations could expand or fail, local populations could increase or decrease, income could become more or less evenly distributed. Technological advance would permit the services provided by a constant stock of capital to increase slowly. Within the third guideline, any country could change its average standard of living by altering the balance between its population and its capital. Furthermore, a society could adjust to changing internal or external factors by raising or lowering the population or capital stocks, or both, slowly and in a controlled fashion, with a predetermined goal in mind. The three points above define a *dynamic* equilibrium, which need not and probably would not "freeze" the world into the population-capital configuration that happens to exist at the present time. The object in accepting the above three statements is to create freedom for society, not to impose a straitjacket.

What would life be like in such an equilibrium state? Would innovation be stifled? Would society be locked into the patterns of inequality and injustice we see in the world today? Discussion of these questions must proceed on the basis of mental models, for there is no formal model of social conditions in the equilibrium state. No one can predict what sort of institutions mankind might develop under these new conditions. There is, of course, no guarantee that the new society would be much better or even much different from that which exists today. It seems possible, however, that a society released

from struggling with the many problems caused by growth may have more energy and ingenuity available for solving other problems. In fact, we believe, as we will illustrate below, that the evolution of a society that favors innovation and technological development, a society based on equality and justice, is far more likely to evolve in a state of global equilibrium than it is in the state of growth we are experiencing today.

GROWTH IN THE EQUILIBRIUM STATE

In 1857 John Stuart Mill wrote:

> It is scarcely necessary to remark that a stationary condition of capital and population implies no stationary state of human improvement. There would be as much scope as ever for all kinds of mental culture, and moral and social progress; as much room for improving the Art of Living and much more likelihood of its being improved.[49]

Population and capital are the only quantities that need be constant in the equilibrium state. Any human activity that does not require a large flow of irreplaceable resources or produce severe environmental degradation might continue to grow indefinitely. In particular, those pursuits that many people would list as the most desirable and satisfying activities of man—education, art, music, religion, basic scientific research, athletics, and social interactions—could flourish.

All of the activities listed above depend very strongly on two factors. First, they depend upon the availability of some surplus production after the basic human needs of food and shelter have been met. Second, they require leisure time. In any equilibrium state the relative levels of capital and population could be adjusted to assure that human material needs are fulfilled at any desired level. Since the amount of material production would be essentially fixed, every improvement in

production methods could result in increased leisure for the population—leisure that could be devoted to any activity that is relatively nonconsuming and nonpolluting, such as those listed above. Thus, this unhappy situation described by Bertrand Russell could be avoided:

Suppose that, at a given moment, a certain number of people are engaged in the manufacture of pins. They make as many pins as the world needs, working (say) eight hours a day. Someone makes an invention by which the same number of men can make twice as many pins as before. But the world does not need twice as many pins. Pins are already so cheap that hardly any more will be bought at a lower price. In a sensible world, everybody concerned in the manufacture of pins would take to working four hours instead of eight, and everything else would go on as before. But in the actual world this would be thought demoralizing. The men still work eight hours, there are too many pins, some employers go bankrupt, and half the men previously concerned in making pins are thrown out of work. There is, in the end, just as much leisure as on the other plan, but half the men are totally idle while half are still overworked. In this way it is insured that the unavoidable leisure shall cause misery all around instead of being a universal source of happiness. Can anything more insane be imagined? [50]

But would the technological improvements that permit the production of pins or anything else more efficiently be forthcoming in a world where all basic material needs are fulfilled and additional production is not allowed? Does man have to be pushed by hardship and the incentive of material growth to devise better ways to do things?

Historical evidence would indicate that very few key inventions have been made by men who had to spend all their energy overcoming the immediate pressures of survival. Atomic energy was discovered in the laboratories of basic science by individuals unaware of any threat of fossil fuel depletion. The

first genetic experiments, which led a hundred years later to high-yield agricultural crops, took place in the peace of a European monastery. Pressing human need may have forced the application of these basic discoveries to practical problems, but only freedom from need produced the knowledge necessary for the practical applications.

Technological advance would be both necessary and welcome in the equilibrium state. A few obvious examples of the kinds of practical discoveries that would enhance the workings of a steady state society include:

- new methods of waste collection, to decrease pollution and make discarded material available for recycling;
- more efficient techniques of recycling, to reduce rates of resource depletion;
- better product design to increase product lifetime and promote easy repair, so that the capital depreciation rate would be minimized;
- harnessing of incident solar energy, the most pollution-free power source;
- methods of natural pest control, based on more complete understanding of ecological interrelationships;
- medical advances that would decrease the death rate;
- contraceptive advances that would facilitate the equalization of the birth rate with the decreasing death rate.

As for the incentive that would encourage men to produce such technological advances, what better incentive could there be than the knowledge that a new idea would be translated into a visible improvement in the quality of life? Historically mankind's long record of new inventions has resulted in crowding, deterioration of the environment, and greater social

inequality because greater productivity has been absorbed by population and capital growth. There is no reason why higher productivity could not be translated into a higher standard of living or more leisure or more pleasant surroundings for everyone, if these goals replace growth as the primary value of society.

EQUALITY IN THE EQUILIBRIUM STATE

One of the most commonly accepted myths in our present society is the promise that a continuation of our present patterns of growth will lead to human equality. We have demonstrated in various parts of this book that present patterns of population and capital growth are actually increasing the gap between the rich and the poor on a worldwide basis, and that the ultimate result of a continued attempt to grow according to the present pattern will be a disastrous collapse.

The greatest possible impediment to more equal distribution of the world's resources is population growth. It seems to be a universal observation, regrettable but understandable, that, as the number of people over whom a fixed resource must be distributed increases, the equality of distribution decreases. Equal sharing becomes social suicide if the average amount available per person is not enough to maintain life. FAO studies of food distribution have actually documented this general observation.

> Analysis of distribution curves shows that when the food supplies of a group diminish, inequalities in intake are accentuated, while the number of undernourished families increases more than in proportion to the deviation from the mean. Moreover, the food intake deficit grows with the size of households so that large families, and their children in particular, are statistically the most likely to be underfed.[51]

In a long-term equilibrium state, the relative levels of popula-

tion and capital, and their relationships to fixed constraints such as land, fresh water, and mineral resources, would have to be set so that there would be enough food and material production to maintain everyone at (at least) a subsistence level. One barrier to equal distribution would thus be removed. Furthermore, the other effective barrier to equality—the promise of growth—could no longer be maintained, as Dr. Herman E. Daly has pointed out:

> For several reasons the important issue of the stationary state will be distribution, not production. The problem of relative shares can no longer be avoided by appeals to growth. The argument that everyone should be happy as long as his absolute share of wealth increases, regardless of his relative share, will no longer be available. . . . The stationary state would make fewer demands on our environmental resources, but much greater demands on our moral resources.[52]

There is, of course, no assurance that humanity's moral resources would be sufficient to solve the problem of income distribution, even in an equilibrium state. However, there is even less assurance that such social problems will be solved in the present state of growth, which is straining both the moral and the physical resources of the world's people.

The picture of the equilibrium state we have drawn here is idealized, to be sure. It may be impossible to achieve in the form described here, and it may not be the form most people on earth would choose. The only purpose in describing it at all is to emphasize that global equilibrium need not mean an end to progress or human development. The possibilities within an equilibrium state are almost endless.

An equilibrium state would not be free of pressures, since no society can be free of pressures. Equilibrium would require trading certain human freedoms, such as producing unlimited

numbers of children or consuming uncontrolled amounts of resources, for other freedoms, such as relief from pollution and crowding and the threat of collapse of the world system. It is possible that new freedoms might also arise—universal and unlimited education, leisure for creativity and inventiveness, and, most important of all, the freedom from hunger and poverty enjoyed by such a small fraction of the world's people today.

THE TRANSITION FROM GROWTH TO GLOBAL EQUILIBRIUM

We can say very little at this point about the practical, day-by-day steps that might be taken to reach a desirable, sustainable state of global equilibrium. Neither the world model nor our own thoughts have been developed in sufficient detail to understand all the implications of the transition from growth to equilibrium. Before any part of the world's society embarks deliberately on such a transition, there must be much more discussion, more extensive analysis, and many new ideas contributed by many different people. If we have stimulated each reader of this book to begin pondering how such a transition might be carried out, we have accomplished our immediate goal.

Certainly much more information is needed to manage the transition to global equilibrium. In the process of sifting the world's data and incorporating it into an organized model, we have become aware of the great need for more *facts*—for numbers that are scientifically measurable but which have not yet been measured. The most glaring deficiencies in present knowledge occur in the pollution sector of the model. How long does it take for any given pollutant to travel from its point of release to its point of entrance into the human body? Does the time required for the processing of any pollutant into

harmless form depend on the level of pollutant? Do several different pollutants acting together have a synergistic effect on human health? What are the long-term effects of low-level dosages on humans and other organisms? There is also a need for more information about rates of soil erosion and land wastage under intensified modern agricultural practices.

From our own vantage point as systems analysts, of course, we would recommend that the search for facts not be random but be governed by a greatly increased emphasis on establishing *system structure*. The behavior of all complicated social systems is primarily determined by the web of physical, biological, psychological, and economic relationships that binds together any human population, its natural environment, and its economic activities. Until the underlying structures of our socioeconomic systems are thoroughly analyzed, they cannot be managed effectively, just as an automobile cannot be maintained in good running condition without a knowledge of how its many parts influence each other. Studies of system structure may reveal that the introduction into a system of some simple stabilizing feedback mechanism will solve many difficulties. There have been interesting suggestions along that line already—for example, that the total costs of pollution and resource depletion be included in the price of a product, or that every user of river water be required to place his intake pipe *downstream* from his effluent pipe.

The final, most elusive, and most important information we need deals with human values. As soon as a society recognizes that it cannot maximize everything for everyone, it must begin to make choices. Should there be more people or more wealth, more wilderness or more automobiles, more food for the poor or more services for the rich? Establishing the societal an-

95-852 O - 73 - 12

swers to questions like these and translating those answers into policy is the essence of the political process. Yet few people in any society even realize that such choices are being made every day, much less ask themselves what their own choices would be. The equilibrium society will have to weigh the trade-offs engendered by a finite earth not only with consideration of present human values but also with consideration of future generations. To do that, society will need better means than exist today for clarifying the realistic alternatives available, for establishing societal goals, and for achieving the alternatives that are most consistent with those goals. But most important of all, long-term goals must be specified and short-term goals made consistent with them.

Although we underline the need for more study and discussion of these difficult questions, we end on a note of urgency. We hope that intensive study and debate will proceed simultaneously with an ongoing program of action. The details are not yet specified, but the general direction for action is obvious. Enough is known already to analyze many proposed policies in terms of their tendencies to promote or to regulate growth. Numerous nations have adapted or are considering programs to stabilize their populations. Some localized areas are also trying to reduce their rates of economic growth.[53] These efforts are weak at the moment, but they could be strengthened very quickly if the goal of equilibrium were recognized as desirable and important by any sizable part of human society.

We have repeatedly emphasized the importance of the natural delays in the population-capital system of the world. These delays mean, for example, that if Mexico's birth rate gradually declined from its present value to an exact replacement value by the year 2000, the country's population would

continue to grow until the year 2060. During that time the population would grow from 50 million to 130 million.[54] If the United States population had two children per family starting now and if there were no net immigration, the population would still continue to grow until the year 2037, and it would increase from 200 million to 266 million.[55] If world population as a whole reached a replacement-size family by the year 2000 (at which time the population would be 5.8 billion), the delays caused by the age structure would result in a final leveling-off of population at 8.2 billion[56] (assuming that the death rate would not rise before then—an unlikely assumption, according to our model results).

Taking no action to solve these problems is equivalent to taking strong action. Every day of continued exponential growth brings the world system closer to the ultimate limits to that growth. A decision to do nothing is a decision to increase the risk of collapse. We cannot say with certainty how much longer mankind can postpone initiating deliberate control of his growth before he will have lost the chance for control. We suspect on the basis of present knowledge of the physical constraints of the planet that the growth phase cannot continue for another one hundred years. Again, because of the delays in the system, if the global society waits until those constraints are unmistakably apparent, it will have waited too long.

If there is cause for deep concern, there is also cause for hope. Deliberately limiting growth would be difficult, but not impossible. The way to proceed is clear, and the necessary steps, although they are new ones for human society, are well within human capabilities. Man possesses, for a small moment in his history, the most powerful combination of knowledge, tools,

and resources the world has ever known. He has all that is physically necessary to create a totally new form of human society—one that would be built to last for generations. The two missing ingredients are a realistic, long-term goal that can guide mankind to the equilibrium society and the human will to achieve that goal. Without such a goal and a commitment to it, short-term concerns will generate the exponential growth that drives the world system toward the limits of the earth and ultimate collapse. With that goal and that commitment, mankind would be ready now to begin a controlled, orderly transition from growth to global equilibrium.

COMMENTARY

In inviting the MIT team to undertake this investigation, we had two immediate objectives in mind. One was to gain insights into the limits of our world system and the constraints it puts on human numbers and activity. Nowadays, more than ever before, man tends toward continual, often accelerated, growth—of population, land occupancy, production, consumption, waste, etc.—blindly assuming that his environment will permit such expansion, that other groups will yield, or that science and technology will remove the obstacles. We wanted to explore the degree to which this attitude toward growth is compatible with the dimensions of our finite planet and with the fundamental needs of our emerging world society—from the reduction of social and political tensions to improvement in the quality of life for all.

A second objective was to help identify and study the dominant elements, and their interactions, that influence the long-term behavior of world systems. Such knowledge, we believe, cannot be gathered by concentrating on national systems and short-run analyses, as is the current practice. The project was not intended as a piece of futurology. It was intended to be, and is, an analysis of current trends, of their influence on each

other, and of their possible outcomes. Our goal was to provide warnings of potential world crisis if these trends are allowed to continue, and thus offer an opportunity to make changes in our political, economic, and social systems to ensure that these crises do not take place.

The report has served these purposes well. It represents a bold step toward a comprehensive and integrated analysis of the world situation, an approach that will now require years to refine, deepen, and extend. Nevertheless, this report is only a first step. The limits to growth it examines are only the known uppermost physical limits imposed by the finiteness of the world system. In reality, these limits are further reduced by political, social, and institutional constraints, by inequitable distribution of population and resources, and by our inability to manage very large intricate systems.

But the report serves further purposes. It advances tentative suggestions for the future state of the world and opens new perspectives for continual intellectual and practical endeavor to shape that future.

We have presented the findings of this report at two international meetings. Both were held in the summer of 1971, one in Moscow and the other in Rio de Janeiro. Although there were many questions and criticisms raised, there was no substantial disagreement with the perspectives described in this report. A preliminary draft of the report was also submitted to some forty individuals, most of them members of The Club of Rome, for their comments. It may be of interest to mention some of the main points of criticism:

1. Since models can accommodate only a limited number of variables, the interactions studied are only partial. It was

pointed out that in a global model such as the one used in this study the degree of aggregation is necessarily high as well. Nevertheless, it was generally recognized that, with a simple world model, it is possible to examine the effect of a change in basic assumptions or to simulate the effect of a change in policy to see how such changes influence the behavior of the system over time. Similar experimentation in the real world would be lengthy, costly, and in many cases impossible.

2. It was suggested that insufficient weight had been given to the possibilities of scientific and technological advances in solving certain problems, such as the development of fool-proof contraceptive methods, the production of protein from fossil fuels, the generation or harnessing of virtually limitless energy (including pollution-free solar energy), and its subsequent use for synthesizing food from air and water and for extracting minerals from rocks. It was agreed, however, that such developments would probably come too late to avert demographic or environmental disaster. In any case they probably would only delay rather than avoid crisis, for the problematique consists of issues that require more than technical solutions.

3. Others felt that the possibility of discovering stocks of raw materials in areas as yet insufficiently explored was much greater than the model assumed. But, again, such discoveries would only postpone shortage rather than eliminate it. It must, however, be recognized that extension of resource availability by several decades might give man time to find remedies.

4. Some considered the model too "technocratic," observing that it did not include critical social factors, such as the effects of adoption of different value systems. The chairman of the

Moscow meeting summed up this point when he said, "Man is no mere biocybernetic device." This criticism is readily admitted. The present model considers man only in his material system because valid social elements simply could not be devised and introduced in this first effort. Yet, despite the model's material orientation, the conclusions of the study point to the need for fundamental change in the values of society.

Overall, a majority of those who read this report concurred with its position. Furthermore, it is clear that, if the arguments submitted in the report (even after making allowance for justifiable criticism) are considered valid in principle, their significance can hardly be overestimated.

Many reviewers shared our belief that the essential significance of the project lies in its global concept, for it is through knowledge of wholes that we gain understanding of components, and not vice versa. The report presents in straightforward form the alternatives confronting not one nation or people but all nations and all peoples, thereby compelling a reader to raise his sights to the dimensions of the world problematique. A drawback of this approach is of course that —given the heterogeneity of world society, national political structures, and levels of development—the conclusions of the study, although valid for our planet as a whole, do not apply in detail to any particular country or region.

It is true that in practice events take place in the world sporadically at points of stress—not generally or simultaneously throughout the planet. So, even if the consequences anticipated by the model were, through human inertia and political difficulties, allowed to occur, they would no doubt appear first in a series of local crises and disasters.

But it is probably no less true that these crises would have

repercussions worldwide and that many nations and people, by taking hasty remedial action or retreating into isolationism and attempting self-sufficiency, would but aggravate the conditions operating in the system as a whole. The interdependence of the various components of the world system would make such measures futile in the end. War, pestilence, a raw materials starvation of industrial economies, or a generalized economic decay would lead to contagious social disintegration.

Finally, the report was considered particularly valuable in pointing out the exponential nature of human growth within a closed system, a concept rarely mentioned or appreciated in practical politics in spite of its immense implications for the future of our finite planet. The MIT project gives a reasoned and systematic explanation of trends of which people are but dimly aware.

The pessimistic conclusions of the report have been and no doubt will continue to be a matter for debate. Many will believe that, in population growth, for instance, nature will take remedial action, and birth rates will decline before catastrophe threatens. Others may simply feel that the trends identified in the study are beyond human control; these people will wait for "something to turn up." Still others will hope that minor corrections in present policies will lead to a gradual and satisfactory readjustment and possibly to equilibrium. And a great many others are apt to put their trust in technology, with its supposed cornucopia of cure-all solutions.

We welcome and encourage this debate. It is important, in our opinion, to ascertain the true scale of the crisis confronting mankind and the levels of severity it is likely to reach during the next decades.

From the response to the draft report we distributed, we

believe this book will cause a growing number of people throughout the world to ask themselves in earnest whether the momentum of present growth may not overshoot the carrying capacity of this planet—and to consider the chilling alternatives such an overshoot implies for ourselves, our children, and our grandchildren.

How do we, the sponsors of this project, evaluate the report? We cannot speak definitively for all our colleagues in The Club of Rome, for there are differences of interest, emphasis, and judgment among them. But, despite the preliminary nature of the report, the limits of some of its data, and the inherent complexity of the world system it attempts to describe, we are convinced of the importance of its main conclusions. We believe that it contains a message of much deeper significance than a mere comparison of dimensions, a message relevant to all aspects of the present human predicament.

Although we can here express only our preliminary views, recognizing that they still require a great deal of reflection and ordering, we are in agreement on the following points:

1. We are convinced that realization of the quantitative restraints of the world environment and of the tragic consequences of an overshoot is essential to the initiation of new forms of thinking that will lead to a fundamental revision of human behavior and, by implication, of the entire fabric of present-day society.

It is only now that, having begun to understand something of the interactions between demographic growth and economic growth, and having reached unprecedented levels in both, man is forced to take account of the limited dimensions of

his planet and the ceilings to his presence and activity on it. For the first time, it has become vital to inquire into the cost of unrestricted material growth and to consider alternatives to its continuation.

2. We are further convinced that demographic pressure in the world has already attained such a high level, and is moreover so unequally distributed, that this alone must compel mankind to seek a state of equilibrium on our planet.

Underpopulated areas still exist; but, considering the world as a whole, the critical point in population growth is approaching, if it has not already been reached. There is of course no unique optimum, long-term population level; rather, there are a series of balances between population levels, social and material standards, personal freedom, and other elements making up the quality of life. Given the finite and diminishing stock of nonrenewable resources and the finite space of our globe, the principle must be generally accepted that growing numbers of people will eventually imply a lower standard of living—and a more complex problematique. On the other hand, no fundamental human value would be endangered by a leveling off of demographic growth.

3. We recognize that world equilibrium can become a reality only if the lot of the so-called developing countries is substantially improved, both in absolute terms and relative to the economically developed nations, and we affirm that this improvement can be achieved only through a global strategy.

Short of a world effort, today's already explosive gaps and inequalities will continue to grow larger. The outcome can only be disaster, whether due to the selfishness of individual countries that continue to act purely in their own interests,

or to a power struggle between the developing and developed nations. The world system is simply not ample enough nor generous enough to accommodate much longer such egocentric and conflictive behavior by its inhabitants. The closer we come to the material limits to the planet, the more difficult this problem will be to tackle.

4. We affirm that the global issue of development is, however, so closely interlinked with other global issues that an overall strategy must be evolved to attack all major problems, including in particular those of man's relationship with his environment.

With world population doubling time a little more than 30 years, and decreasing, society will be hard put to meet the needs and expectations of so many more people in so short a period. We are likely to try to satisfy these demands by overexploiting our natural environment and further impairing the life-supporting capacity of the earth. Hence, on both sides of the man-environment equation, the situation will tend to worsen dangerously. We cannot expect technological solutions alone to get us out of this vicious circle. The strategy for dealing with the two key issues of development and environment must be conceived as a joint one.

5. We recognize that the complex world problematique is to a great extent composed of elements that cannot be expressed in measurable terms. Nevertheless, we believe that the predominantly quantitative approach used in this report is an indispensable tool for understanding the operation of the problematique. And we hope that such knowledge can lead to a mastery of its elements.

Although all major world issues are fundamentally linked,

no method has yet been discovered to tackle the whole effectively. The approach we have adopted can be extremely useful in reformulating our thinking about the entire human predicament. It permits us to define the balances that must exist within human society, and between human society and its habitat, and to perceive the consequences that may ensue when such balances are disrupted.

6. We are unanimously convinced that rapid, radical redressment of the present unbalanced and dangerously deteriorating world situation is the primary task facing humanity.

Our present situation is so complex and is so much a reflection of man's multiple activities, however, that no combination of purely technical, economic, or legal measures and devices can bring substantial improvement. Entirely new approaches are required to redirect society toward goals of equilibrium rather than growth. Such a reorganization will involve a supreme effort of understanding, imagination, and political and moral resolve. We believe that the effort is feasible and we hope that this publication will help to mobilize forces to make it possible.

7. This supreme effort is a challenge for our generation. It cannot be passed on to the next. The effort must be resolutely undertaken without delay, and significant redirection must be achieved during this decade.

Although the effort may initially focus on the implications of growth, particularly of population growth, the totality of the world problematique will soon have to be addressed. We believe in fact that the need will quickly become evident for social innovation to match technical change, for radical reform of institutions and political processes at all levels, including

the highest, that of world polity. We are confident that our generation will accept this challenge if we understand the tragic consequences that inaction may bring.

8. We have no doubt that if mankind is to embark on a new course, concerted international measures and joint long-term planning will be necessary on a scale and scope without precedent.

Such an effort calls for joint endeavor by all peoples, whatever their culture, economic system, or level of development. But the major responsibility must rest with the more developed nations, not because they have more vision or humanity, but because, having propagated the growth syndrome, they are still at the fountainhead of the progress that sustains it. As greater insights into the condition and workings of the world system are developed, these nations will come to realize that, in a world that fundamentally needs stability, their high plateaus of development can be justified or tolerated only if they serve not as springboards to reach even higher, but as staging areas from which to organize more equitable distribution of wealth and income worldwide.

9. We unequivocally support the contention that a brake imposed on world demographic and economic growth spirals must not lead to a freezing of the *status quo* of economic development of the world's nations.

If such a proposal were advanced by the rich nations, it would be taken as a final act of neocolonialism. The achievement of a harmonious state of global economic, social, and ecological equilibrium must be a joint venture based on joint conviction, with benefits for all. The greatest leadership will be demanded from the economically developed countries, for

the first step toward such a goal would be for them to encourage a deceleration in the growth of their own material output while, at the same time, assisting the developing nations in their efforts to advance their economies more rapidly.

10. We affirm finally that any deliberate attempt to reach a rational and enduring state of equilibrium by planned measures, rather than by chance or catastrophe, must ultimately be founded on a basic change of values and goals at individual, national, and world levels.

This change is perhaps already in the air, however faintly. But our tradition, education, current activities, and interests will make the transformation embattled and slow. Only real comprehension of the human condition at this turning point in history can provide sufficient motivation for people to accept the individual sacrifices and the changes in political and economic power structures required to reach an equilibrium state.

The question remains of course whether the world situation is in fact as serious as this book, and our comments, would indicate. We firmly believe that the warnings this book contains are amply justified, and that the aims and actions of our present civilization can only aggravate the problems of tomorrow. But we would be only too happy if our tentative assessments should prove too gloomy.

In any event, our posture is one of very grave concern, but not of despair. The report describes an alternative to unchecked and disastrous growth and puts forward some thoughts on the policy changes that could produce a stable equilibrium for mankind. The report indicates that it may be within our reach to provide reasonably large populations with a good material life plus opportunities for limitless individual and

social development. We are in substantial agreement with that view, although we are realistic enough not to be carried away by purely scientific or ethical speculations.

The concept of a society in a steady state of economic and ecological equilibrium may appear easy to grasp, although the reality is so distant from our experience as to require a Copernican revolution of the mind. Translating the idea into deed, though, is a task filled with overwhelming difficulties and complexities. We can talk seriously about where to start only when the message of *The Limits to Growth,* and its sense of extreme urgency, are accepted by a large body of scientific, political, and popular opinion in many countries. The transition in any case is likely to be painful, and it will make extreme demands on human ingenuity and determination. As we have mentioned, only the conviction that there is no other avenue to survival can liberate the moral, intellectual, and creative forces required to initiate this unprecedented human undertaking.

But we wish to underscore the challenge rather than the difficulty of mapping out the road to a stable state society. We believe that an unexpectedly large number of men and women of all ages and conditions will readily respond to the challenge and will be eager to discuss not *if* but *how* we can create this new future.

The Club of Rome plans to support such activity in many ways. The substantive research begun at MIT on world dynamics will be continued both at MIT and through studies conducted in Europe, Canada, Latin America, the Soviet Union, and Japan. And, since intellectual enlightenment is without effect if it is not also political, The Club of Rome also will encourage the creation of a world forum where statesmen,

policy-makers, and scientists can discuss the dangers and hopes for the future global system without the constraints of formal intergovernmental negotiation.

The last thought we wish to offer is that man must explore himself—his goals and values—as much as the world he seeks to change. The dedication to both tasks must be unending. The crux of the matter is not only whether the human species will survive, but even more whether it can survive without falling into a state of worthless existence.

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95-852 O - 73 - 13

[From Time, Aug. 14, 1972]

CAN THE WORLD SURVIVE ECONOMIC GROWTH?

(TIME Essay by George J. Church)

In biology, growth is a distinguishing mark of life; in economics it has long seemed the *sine qua non* of the good life. Adam Smith argued in 1776 that "it is not the actual greatness of national wealth, but its continual increase, which occasions a rise in the wages of labor." Economists ever since have insisted that only a rapid increase in output could lift mankind out of poverty. Politicians of every ideology have dedicated themselves to raising production, to the applause of their constituents.

Now, however, many scientists and social reformers have begun to regard perpetual economic growth as malignant. Their increasingly fashionable fear is that production increases will destroy civilization, either by stripping the earth of natural resources or by choking humanity in a cloud of pollution. Sicco Mansholt, outgoing president of the European Common Market Commission, has remarked that in Western Europe, American and Japan, gross national product "has been thought of as something sacred—but G.N.P. is diabolical." Walter Heller, a member of TIME's Board of Economists, complains that a speaker who ventures a good word for rising output is immediately assailed as a "growth maniac" or an "abominable growthman."

Antigrowth sentiment has been swelling for years, but the biggest push came from the appearance last winter of a 197-page book, *The Limits to Growth*, which avowedly aims at "a Copernican revolution of the mind" (TIME, Jan. 24). It was prepared by a team of 17 scientists, ranging from an Iranian population expert to a Norwegian specialist on pollution. The study was begun by Professor Jay Forrester, an M.I.T. pioneer in computer analysis of likely future trends, and completed by his 30-year-old protégé, Dennis L. Meadows, a business professor who has recently moved from M.I.T. to Dartmouth. The study was sponsored, endorsed and publicized by the Club of Rome, an organization of distinguished industrialists, bankers and scientists from 25 countries.

Meadows is no latter-day Malthus prophesying doom on the basis of intuition; instead he has produced the first vision of the apocalypse ever prepared by computer. His team built a computer model of the world, fed the machine masses of data on population and industrial growth rates, farm yields and the like, and constructed "feedback loops" to gauge the effects of changes in one variable, like food production, on another, like birth rates. In restrained, nonhysterical, at times almost apologetic language, the team insists that unchecked growth can have only one outcome: "A rather sudden and uncontrollable decline in both population and industrial capacity" some time before the year 2100.

Meadows' villain is "exponential growth" at a regular annual percentage. Each year's growth yields a bigger absolute increase because it is applied to a larger base; the result is that growth accelerates rapidly, like compound interest. In the M.I.T. computers, exponential growth showed a terrifying tendency to "overshoot and collapse." The study asserts that if the world's population continues to grow at about 2% annually, and global industrial output expands about 7% a year (as they do now), then some time during the life span of children born today, the world will begin running out of natural resources such as coal, oil and metals. For lack of them, industries will collapse by the mid-21st century (give or take a few decades). Because industries will no longer be able to produce enough fertilizers, pesticides or medicines, famine and epidemic will kill much of the human race, and the lives of the rest will fit Thomas Hobbes' description: "Nasty, brutish and short."

The study closes almost every escape hatch. Technology, it concedes, can multiply usable resources; but if that happens, industries will grow at an exponential rate and will ultimately foul the atmosphere enough to kill most people. Pollution per unit of output could perhaps be cut by three-fourths. But that would do nothing to check the exponential growth of population, and the world would soon run out of arable land, leading to mass starvation. Population growth could be halted; but that would only postpone the cataclysm unless industrial growth were stopped too. If it persisted, output would soon quadruple, canceling the benefits of the 75% reduction in pollution; thereafter pollution would rise dramatically, causing hecatombs by poisoning. There is only one way out, says the report: economic as well as population growth must be stopped cold some time between 1975 and 1990 by holding world investment in new plant and machinery equal to the rate at which physical capital wears out.

This status quo prescription—the report calls it "global equilibrium"—is as chilling as the doomsday prophecy. Halting economic growth is not merely a matter of the already affluent giving up such frills as electric toothbrushes or power windows. Sacrifices would be made by the poor, who have not yet collected the benefits of the industrial revolution. Economic growth does not necessarily guarantee that the unemployed Mississippi Delta black or the Vietnamese peasant will some day enjoy a balanced diet or a private room. But shopping growth could all too easily foreclose even the possibility.

Redistribution of existing wealth is no solution, because the rich and middle classes would not give up their wealth unless it was forcibly taken from them. Thus the redistribution would imply a series of violent revolutions and wars over the ownership of oil wells, ore mines and fertile farm land. At best, even these could produce only an equality of misery.

More than that, a no-growth world would have extreme difficulty providing either social justice or freedom. It is hard to see how growth could be halted, or even substantially slowed, without a world dictatorship—the more so as citizens of underdeveloped countries already suspect that the no-growth argument is an elitist, aristocratic, white man's conspiracy to lock them into perpetual poverty. It would do little good to stop growth in the U.S. if it raged on in Algeria and Indonesia. At minimum, people would have to be told that they could not buy the flush toilets or transistor radios that they desire because computers had decreed that no more resources could be invested in producing them. Corporations would have a hard time expanding; for every one that did expand, another company would have to contract. Could freedom of speech survive? Demagogues would surely promise comfort to the poor if only growth could be resumed; that siren song would have to be silenced.

Even the authors of the Club of Rome report confess that there is only one conceivable reason for stopping growth: that is the only way to prevent certain global cataclysm. But is it really?

The book presents an elusive target because the Club of Rome will not publish until next month the statistics that Meadows used. Already, though, critics are sharply assailing Meadows' methodology. Their most telling point is that the M.I.T. computer shows only the "bad" trends—such as population and economic growth—increasing exponentially. Some tendencies that might save the world are allowed only "linear" growth, as in simple interest rates. The difference is dramatic. At exponential rates, anything that grows 7% a year would double in size in just over ten years and increase by 86,672% in 100 years. But at linear rates, a 7% increase would lead to a doubling in just over 14 years and an increase of 700% in 100 years.

Critics of the Club of Rome report insist that exponential growth is also possible in the technology that enables society to utilize new resources, wring more food from the land and curb pollution. In the resources field, some experts sketch this scenario: long before resources run out, scarcities would force price boosts. The expense would prod industrialists and consumers to substitute one material for another, develop recycling techniques to use existing supplies more efficiently, and redouble efforts to find ways of using materials—for example, oil-bearing shale—that were previously uneconomic or technically impossible to exploit. Before long, commercial harnassing of thermonuclear fusion could make available limitless quantities of low-cost energy, which could in turn be used to unlock new raw materials from the earth.

Ecologist Barry Commoner, a vehement foe of mindless growth, considers Meadows' treatment of pollution "quite simplistic." It assumes that more growth inevitably means more pollution. Yet the alarming rise in pollution, says Commoner, has been caused not by growth per se but by changes in the composition of growth—for example, the postwar shifts from soaps to detergents. Shifting back to cleaner (and costlier) products and techniques could decrease pollution much more than the Meadows team foresees, while permitting output to continue rising. In essence, the Meadows team projected current trends into the future without analyzing how man might alter them. The whole exercise, say critics, proves again that the past is a shaky gauge of the future, and that the value of the conclusions coming out of a computer depends totally on the quality of the assumptions programmed into it. Computer men sum up this idea with the acronym GIGO—"garbage in, garbage out."

Yet *The Limits to Growth* cannot be dismissed as just another cry of wolf. The catastrophes that it predicts *could* happen. Indeed, the world is now getting an ominous foretaste of some disasters. In Japan, for example, superexponential growth has so befouled the air and water that pollution has directly caused outbreaks of serious disease and death.

Meadows probably erred in placing the potential day of reckoning around 2050, and whether it comes then or in, say, 3050 makes a gargantuan difference to people alive today—and to their immediate heirs. The later it is, the more chance there is in the interim of raising the world's poor toward a decent life. But only a superoptimist would insist that growth can continue forever; that would presuppose that resources are literally infinite. Even if the earth's resources and its capacity to absorb pollution could be extended without limit—or if humanity could colonize other worlds—no one could be certain that that could be done rapidly enough to permit infinite growth at the pace and of the type occurring today. To banish the Club of Rome's nightmares, some changes in growth patterns should start now.

Economists, ecologists and entrepreneurs should strive to increase clean, nonpolluting growth and to restrain the kind of growth that exhausts resources and pollutes the environment. One problem is that there is no reliable indicator that measures and distinguishes between different kinds of growth. Economic performance is gauged by the gross national product, a truly gross and misleading measure. Activities that are useless (like the printing of reports that the recipients throw in the wastebasket without reading) or even destructive (the development of highly polluting production technologies) swell G.N.P. as long as money is spent on them. At best, G.N.P. tends to overemphasize the kind of growth symbolized by steel, stamping presses, cars and dishwashers—precisely the kind that chews up natural resources and pours out pollution. In theory, a dollar of salary paid to a Latin scholar weighs as heavily as a dollar of wages paid to an auto worker; but in practice, hiring six auto workers increases G.N.P. more than hiring six public school teachers. The auto workers turn out a product that is sold for more dollars that further swell G.N.P.; the teachers do not.

A better, even if less precise measure of economic growth might be "an increase in material well-being." In poor countries, the redefinition is not so important: their people still need every cooking pot, pair of shoes and bicycle that can be produced. But in the industrialized world, and especially in the U.S., it is possible to envision a policy that would devote a dwindling share of new investments to traditional industry while channeling more into such tasks as cleaning streets, improving education and law enforcement, upgrading mass transit and expanding low-cost medical service. Such a program in the developed nations might cause G.N.P. growth to slow, though not stop, since stethoscopes use less metal than refrigerators do. For that very reason, this program would conserve resources and minimize pollution, and it could result in a truer as well as a cleaner kind of economic growth. Litter-free streets, safer trains, better medical care and increased protection against muggings might well increase human well-being more than a higher output of cars, chemicals and electric can openers. Unemployment would not rise; fewer people would work in basic industries, but more people would find jobs as teachers, park attendants and medical technicians. Poorer nations could continue to concentrate on increasing G.N.P., though the poor, too, should ponder whether they might not be better off building bicycle plants instead of auto assembly lines, even if car factories raise G.N.P. more.

There are drawbacks. The Government would have to take over more of the direction of the economy, taxing away dollars that citizens otherwise would use for private purchases and pouring them into public investments. How the money left in the private economy would be spent could be mostly left to the market, but the Government would have to intervene there too. Never again, for example, could industry assume that almost any new production technique that is developed must be put into use, regardless of whether it conserves or depletes resources, reduces or increases pollution. Government may have to guide the decisions, though that could be done by tax, depreciation and contracting policy rather than by dictatorial fiat.

To carry out completely such a shift in public policy, and the change in popular psychology on which it must be based, could take decades, even generations. M.I.T. computers to the contrary, society probably has the time. But it must not squander that time in a heedless pursuit of the wrong kind of growth.

THE COMPUTER THAT PRINTED OUT W*O*L*F*

By Carl Kaysen

"THE Limits to Growth" is a brief, forceful, easily read polemic which has already generated many times its own weight in enthusiastic encomia and equally strong condemnations.[1] It advances a familiar, indeed fashionable, thesis. The goals and institutions of our present world society stimulate population growth and production increase at a rate that cannot be sustained. Further, and perhaps less familiarly, we are now about a generation from the point of no return, after which the world must suffer a catastrophic drop in numbers and wealth, no matter what is then done to restrain further growth. The argument is presented with a sufficient panoply of graphs, flow diagrams, references to the World Model and the new discipline of System Dynamics, and invocations of the computer to produce an aura of scientific authority for the conclusions. They have the additional weight of the endorsement of a prestigious private international group of respected businessmen, officials and academics, The Club of Rome, in a commentary appended to the study and signed by its executive committee. It is my contention that the authors' analysis is gravely deficient and many of their strongest and most striking conclusions unwarranted. None the less, it draws attention to a number of difficult and important problems which must be faced, including the question of whether its whole approach is helpful or harmful in dealing with these real problems.

The backbone of the argument of "Limits" is simple, and requires little elaborate intellectual machinery to develop. Many significant variables that characterize our global society, in particular population and industrial production, have been growing exponentially over the last century, that is, at a constant percentage rate, and thus showing a greater and greater absolute increment each year. The processes that determine this persistent growth at constant (roughly) percentage rates lie deep in the structure of our social order, and unless we deliberately make drastic changes in it, they may be expected to persist and continue

[1] "The Limits to Growth," by D. H. Meadows, D. L. Meadows, J. Randers and W. W. Behrens III. New York: Universe Books (A Potomac Associates Book), 1972.

to generate exponential growth in the future. Many important physical aspects of the world, however, are finite, and their finiteness implies that exponential growth cannot go on indefinitely, without, so to speak, bumping into the limits. In particular, supplies of cultivable land, reserves of mineral resources and the capacity of the earth to "absorb" pollution are finite, and one or another of these (or some combination of them) sets a ceiling level for population and industrial output.

What is more important, when one of the exponentially growing variables reaches the ceiling, it does not simply remain at the limit value, but rather moves sharply down to a much lower level in a process of catastrophic decline. Thus when industrial production, for example, reaches a ceiling level set by limits on mineral resources, it does not simply remain there but plunges from a wealth- to a poverty-level in a short space of time. It is this proposition, together with some of the characteristic time dimensions of the process that both constitute the core of novelty in the book and justify its urgent call for rapid and drastic action.

This characteristic sharp shift from growth to decline in turn reflects two features of the formal model which underly the computations and arguments presented in the book.[2] The first is that the several variables and limits are all interrelated in a system in which growth in each of the main variables is reinforced by growth in the others. The second is that changes in some elements of the system have their effects on others only after a long lag. Thus, for example, a fall in the birth rate affects the demand for food fully only after a lag determined by the average length of life.

The question of how the system behaves when it reaches or approaches a limit is the central question of interest, and it is worth repeating that the kind of behavior which the authors find characteristic of their system is what gives their argument both its interest and its compelling quality. The fact that some limits exist, that the earth is in principle finite, is hard to deny, but does not in itself lead to any very interesting conclusions. Examples of growth systems are known that display quite different behavior as they approach their natural limits than the sharp reversals portrayed in "Limits." For instance, a system in which

[2] The details of the model are not given in the present volume, but are developed in a series of technical papers listed in its appendix, and in the book, "World Dynamics," by Jay Forrester (Cambridge, Mass.: Wright-Allen Press, 1971). Forrester is the intellectual father of System Dynamics.

the rate of growth of the major variables was proportional to their distance from their limits would show a smooth, gradual, stable adaptation to its growth ceiling.

Further, the response times of the system the authors present to changes in some of the key variables are such that we must anticipate the possibility of castastrophe by half a generation or more, in order to have time to act and avert it. By the time we see the whites of their eyes, our guns will no longer fire. Thus the book's chief conclusion, endorsed by its sponsors in The Club of Rome, is that we must planfully, radically reorganize the fundamental institutions of our social world soon or face an unmanageable crisis not so late. To do so, we must now recognize the need, and begin to devise the means.

The analysis supporting these conclusions is unconvincing. It contains at least three kinds of flaws, each of which alone would justify a skeptical view of the result. Further, the first two are deficiencies of principle, which operate at the same level of simplification, approximation and qualitative generality that the authors attribute to their analysis. The most important question concerns the nature of the limits that enforce the growth ceiling in the model. Basically, there are two: arable land and the supply of exhaustible minerals. The first operates primarily on population, the second on industrial production. In order to demonstrate the ineluctability of the limits, and unimportance of the precise magnitudes assigned to them, the authors show that doubling the productivity of agricultural land, or doubling the reserves of natural resources, leads to no qualitative change in the behavior of the system, and only a relatively brief postponement of the moment of catastrophe. Pollution operates as a limit too, but somewhat more indirectly, through its effect on length of life and thus on population. Making pollution control more effective is seen as possible only with sharply increasing costs; thus an economic limit is built into the model in respect to pollution control that functions in the same way as the physical limits on agricultural land and mineral resources. The various alternative assumptions the authors work into the model always rely on one or more of these limits to bring about the characteristic crisis of the system. Even the variant of the model described as "utilizing a technological policy in every sector of the world model to circumvent in some way the various limits to growth" (p. 141) in fact incorporates all three limits—though they oper-

ate in a more distant future than in other variants, and the onset of catastrophic decline in population occurs only at the end of the twenty-first century.[8]

The notion that such limits must exist gains plausibility from the use of physical terms to indicate the relevant quantities—acres of arable land, tons of chrome ore reserves—implicitly invoking the physical finiteness of the earth as the ultimate bound. But this is fundamentally misleading. Resources are properly measured in economic, not physical, terms. New land can be created by new investment, as when arid lands are irrigated, swamps drained, forests cleared. Similarly, new mineral resources can be created by investment in exploration and discovery. These processes of adding to the supplies of "fixed" resources have been going on steadily throughout human history. Indeed, the authors themselves in effect recognize this when they describe the pollution limit not in physical terms, but in terms of the increasing costs of achieving higher and higher degrees of pollution control.

However, once the problem is recognized as one of cost limits, not physical limits, it appears in a different light. The force of rising costs as mines go deeper or exploit thinner veins, or as drier and more distant lands need more water brought from farther sources and the like, meets the force of advancing technology, which brings down the costs of using existing resources and literally creates new resources by bringing within the bounds of cost feasibility materials or methods which formerly lay outside it. Thus, for example, the Hall process for reducing aluminum oxide by bringing the costs of the metal down to a level that made it an industrially usable material rather than a jeweller's curiosity, literally added hundreds of millions of tons to our reserves of metal ores. New ways of locating oil pools and new ways of exploiting them have combined to keep oil reserves—measured in terms of annual consumption—about constant over the past generation, though the actual rate of consumption has been growing exponentially. In general, the relative prices of mineral raw materials and agricultural products have not been rising, and the share of minerals (even allowing for imports) and agricultural output in total production have been falling fairly steadily over a long period in the United States. This is

[8] The plot of this model (fig. 42, p. 140) shows an inexplicable and incredible rise in food consumption per capita, although its timing does not suggest that the population has overeaten to the point of extinction.

also true in other developed countries for which we have good evidence. While comparably good quantitative evidence for the whole world is not available, and such evidence as there is has not been assembled and analyzed, the best guess is that for the world as a whole, the share of extractive industries in output has been falling over the long period.[4]

In sum, the advance of technology, like the growth of population and industry, has also been proceeding exponentially. In the United States—again the society for which the best data are available over a long period of time—the average annual rate of technological growth over the last half-century for the private economy as a whole has been in the neighborhood of two percent. Broadly speaking, this means that a representative bundle of inputs—labor, capital, raw materials, land—of constant value (in constant prices) will each year yield two percent more output than the year before. As "Limits" points out in urging the force of exponential growth, a two percent annual growth rate corresponds to a 35-year doubling time. Thus, technical progress over the life of a generation has made it possible for our children to get twice as much output from the same bundle of inputs as their parents. There is even some evidence that the rate of technological advance in the United States has speeded up in recent years, but it is not conclusive. Other industrial countries also show exponential growth in technology; some, such as Germany and Japan in recent years, at higher rates than the United States but the data pertaining to them cover only a short recent period.

Once an exponentially improving technology is admitted into the model, along with exponentially growing population and production, the nature of its outcomes changes sharply. The inevitability of crisis when a limit is reached disappears, since the "limits" themselves are no longer fixed, but grow exponentially too. The qualitative character of the results then depends on the fine details of the model, and, in particular, on the differences between the growth rates of the most important variables. Catastrophes need no longer be the rule, and more stable outcomes, in

[4] At this point, the reader probably feels uneasily that there must be some flaw in the argument. Surely the earth is finite, and even the wonders of technology must have some limit. The earth is finite, to be sure, and without broaching the larger question of whether the universe is or is not, it can be shown that the finiteness of the earth does not in itself set limits to what technology might accomplish that are relevant to the time horizons of the kind of argument with which we are concerned. I owe to Professor Robert Socolow of Princeton University a calculation that shows that in terms of physical limits alone, *i.e.* available matter and energy, the earth could support a population at least 1,000 times the present one at the current U.S. per capita income level.

particular continuing growth at low rates, now become possible.

The second major flaw in the authors' analysis lies in the total absence of adjustment mechanisms of any kind in the model. Certain behavioral relations among the major variables are laid down, the magnitudes of their parameters determined by average behavior over the past, and then the relations projected unchangingly into the future. That is not how real social mechanisms work. Especially in the workings of the economy, adjustment mechanisms play a crucial role. The most important of these is price: as a resource becomes scarce, the consequent rise in price leads to savings in use, to efforts to increase supply, and to technical innovation to offset the scarcity. All economists know that these adjustment mechanisms are far from perfect and smoothly functioning. Yet they are and have historically been sufficiently powerful to mediate very large shifts in use of resources location, of population and patterns of consumption. Prices play no significant role in the basic logical structure that supports the argument of "Limits," although it is precisely their function to make smooth transitions possible as scarcities and demands change. Their absence is not unrelated to the characteristically unstable responses the model system of "Limits" displays. Only the effort of constructing another and much more complex model could show in detail what kind of stabilizing influence the incorporation of price changes and responses to them would exert. It is, however, well known that dynamic models structurally similar to those employed in "Limits," that characteristically display various forms of unstable behavior in the absence of prices as variables, are stabilized by the incorporation of prices and normal responses to price changes.

The third defect of the analysis is of a quite different order, one of detail rather than of principle. It is simply the failure of the authors to use available knowledge fully, effectively, or in some cases, at all. No one detail is of great importance, but together, they weaken seriously the claim of the work to respect. The most important single example is the authors' treatment of the determinants of population growth. Nowhere in their discussion do they acknowledge the great fact of demographic history in the Western world: the adjustment of birth rates to death rates. Our understanding of this "demographic transition" is far from complete; even if the underdeveloped countries repeated the same pattern over the same (relative) time period, they and the world

would not be free of appropriate concern over the magnitude of population growth. But what should we think of a model of a process in which population growth plays a crucial role that simply ignores this central, elementary and familiar fact? Or to take another example of much less significance to the central argument, the discussion of equality and economic growth (p. 42–44) closes with an italicized warning that "the process of economic growth, as it is occurring today, is inexorably widening the absolute gap between the rich and the poor nations of the world." The "absolute gap," *i.e.* the difference in dollars between average per capita income in the United States and, say, Peru, is growing and, given their present levels, will probably continue to do so for a very long time. But is that interesting or important? The *relative* gap between average income in many of the poorer countries and the industrial West is narrowing, and that is what is relevant to the question of equality. Economic history shows that, after the early stages of urbanization and the development of commerce, economic growth has tended to greater equality of incomes, both within nations and between them. A complete syllabus of errors would be tediously long; perhaps the length of the list is the natural result of the process of reinventing economics, demography and much else as System Dynamics.

So much for the analysis. Can the major conclusion stand alone on its intuitive (or counter-intuitive?) merits without the analytic underpinnings? Is there merit in the proposition that we must seek now to move as rapidly as possible to the state of "global equilibrium" defined by stability of both population and capital, and that failure to do so invites catastrophe? After all, this proposition is now frequently advanced on the basis of much simpler arguments than those we have examined. Briefly, and simply, the answer is "No." There are no credible reasons for believing that the world as a whole cannot maintain a fairly high rate of economic growth (though not necessarily the present one) over a long period of time into the future. Further, if it becomes necessary, for whatever reason, to slow down the growth rate, a relatively smooth transition from higher to lower rates will be perfectly possible, and not achievable only through the mechanism of catastrophe. Moreover, whatever is done to slow down the rate of population growth, population will continue to grow, especially in the poorer countries, for a long time. Only

an *increased* rate of economic growth in those countries will make it at all possible for them to deal with their unavoidable population increases without catastrophe. The large poor countries contain in aggregate a substantial share of the world's people, and thus increased growth for them will have some reflection in world totals. Further, it is difficult or even impossible to conceive of continued substantial economic growth in the poor countries in general taking place in a context of economic stagnation in the industrialized world. Thus, seen both in terms of need and of feasibility, the prospect for the foreseeable future is continued long-term economic growth, perhaps at rates lower than those currently observed, and with quite a different distribution of rates as among countries.

In the legend, there were in the end, real wolves. In the world today, there are real and difficult problems attendant on economic growth as we now experience it. The social-economic system is *not* self-correcting or self-managing; sustained, self-conscious efforts are necessary to deal with the problems, and they often must be maintained against strong resistance. Two of the authors' three central concerns, population growth and pollution, do indeed present genuinely urgent and difficult problems. A third equally important and difficult one, mentioned in "Limits," but only in passing, is the assessment of the indirect consequences of technical change, the unanticipated "side effects" that can sometimes outweigh the benefits. Present social mechanisms are not adequate for coping with any of the three, and the kinds of changes required to do so more effectively meet strong opposition at every level, from that of the individual family to organized interest groups and governments. From one point of view, all three problems can be seen as examples of "external effects," where costs and benefits of particular actions are not borne by the primary actors and thus fall outside the reach of the price system as it usually functions and the control of the incentives and adjustment mechanisms it provides.

In each case, the problem is to find a set of supplementary adjustment mechanisms and incentive systems which can guide the relevant actors to socially more desirable choices, a proposition easy to state in the abstract and difficult to realize in the concrete. In many situations we lack knowledge of the likely consequences of specific actions; in many, those who benefit from present arrangements or think they do resist change, while those

who might benefit from change may lack both knowledge and power. In many situations we lack reliable indicators of what is desirable in an overall sense, and the machinery for resolving conflicting judgments is inadequate. Determined effort to deal with these problems is important. Failure to pay proper attention to them might well result in serious troubles, though they are unlikely to be of a kind which can properly be termed catastrophic. And, though there is widespread discussion of many of these problems and considerable social effort at dealing with some of them, it can be plausibly asserted that it falls far short of what is required.

Finally, therefore, how much does "crying Wolf" help to direct social energies toward improving our responses to these problems? In principle, it is not only useful, but indispensable. The social mechanism is made up of human beings moved by passion far more than by reason. The mobilization of feeling that is the necessary prelude to all but the most routine social action requires some stimulus stronger than a sound argument. But to be effective, the cry must be well directed: the wolves must be imminent and they must indeed be wolves. On this score we can give only a moderate grade to "Limits," or more properly, to its sponsors in The Club of Rome. The problems they call us to attend are real and pressing. But none are of the degree of immediacy that can rightly command the urgency they feel. Indeed, at least two problems of worldwide consequence outside the scope of this work seem to be more urgent than any it deals with: the creation of an international order stable enough to remove the threat of nuclear war, and the diminution of the staggering inequalities in the international distribution of wealth. A good sentry does not cry up tomorrow's wolves and ignore today's tigers.

Commentary

Growth and Its Enemies

Rudolf Klein

One of the characteristics of the human race, a look at current bookstore displays would suggest, is that it is the only species of animal which worries obsessively about its own future. What religious prophecy was to the past, social prophecy has become to the present: predicting the future of man in this life as distinct from the next—a sort of communal fortune-telling. Any roll call of contemporary exponents of the art would include Herman Kahn, Herbert Marcuse, John Kenneth Galbraith, Marshall McLuhan, among others. Mostly, there is a thin dividing line between prediction and prescription, prophecy and propaganda; between those who purport to be neutrally observing events and those committed to preaching what ought to be happening.

Although prediction appears to be a growth share on the cultural stock exchange, interest in the future is obviously not a new phenomenon. Leaving religious prophecy aside, even the secular variety can be traced back for some centuries. What appears to be new is the intellectual industrialization of social prophecy which, like some other forms of research, is rapidly entering the mass-production stage. On the one hand, there are the academics in search of as yet unclaimed territories to stake out. On the other, there are the mass media, hungry for new ideas to transmit before they are worn out by overexposure. So futurology becomes a new academic discipline, with its own institutions, and its own products displayed in the windows of the press and television.

It is as the latest model off this assembly line that *The Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind** is of some significance. By now its recommendations are familiar. To avoid a "global crisis" within the next hundred years or so, both the world population and the world economy must be stabilized within the next few decades. If control by eventual catastrophe is to be avoided, a "global equilibrium" must be achieved, with the world population fixed at roughly its present size and the average income per head at about $1,800 a year—half the present U.S. income and roughly equal to the current European income. Otherwise an overpopulated world, corrupting its environment and exhausting its resources, faces an inevitable cataclysm.

Dramatic though these recommendations are, paradoxically they are the least interesting aspect of this study. It is as a variation peculiar to our own times and culture on what is a long tradition of social prophecy that *The Limits to Growth* deserves looking at: less for what it tells us about the future than for what it shows us about the present.

To start with, *The Limits to Growth* is itself an example of the intellectual industrialization of social prophecy. Commissioned by the Club of Rome—an international consortium of intellectuals concerned to "foster understanding of the varied but independent components . . . that make up the global system"—the study was financed by the Volkswagen Foundation and carried out by an MIT team under the direction of Dr. Dennis L. Meadows. It involved systems analysis—that is constructing a highly simplified model of the "real" world and expressing in a series of mathematical equations the relationship among the factors selected. The study also, inevitably, used a computer. So the book is the product of a process which shares many of the characteristics of the industrial system: in particular, the specialization of labor and the use of mechanical tools.

So much for what is new about the technology of this particular study. But it ought to be seen also in the context of the Western prophetic tradition—with which it has more in common than its manner of production might suggest. This tradition has two main themes which come together in a somewhat unexpected way in *The Limits to Growth*. There is the theme of apocalyptic catastrophe: the threat of doom to come. And there is the theme of millennial hope: the promise of eventual human perfectibility.

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* Donnella H. Meadows, Dennis L. Meadows, Jorgen Randers, William W. Behrens III, Universe Books, 205 pp., $6.50 clothbound ($2.75 paper).

The theme of apocalyptic catastrophe runs through the history of Western Europe in the Middle Ages and beyond. There were regular prophecies of approaching devastation by wind and storm, drought and famine, pestilence and earthquake; often, indeed, a precise date was given for the impending catastrophe and when the Antichrist, the Red Dragon with Seven Heads and Ten Horns, or the Tyrant of the Last Days would appear. Equally regularly sects and movements would arise of the select who knew both how to avoid the doom and how to achieve the millennium: the 13th-century Pastoureaux who impartially killed Jews and clergy, the 14th-century flagellants, and over several centuries, various varieties of the Free Spirits. The doctrine of this last sect, a sort of mystical anarchism, has some curiously modern overtones: "When a man has truly reached the great and high knowledge, he is no longer bound to observe any law or any command, for he has become one with God. . . . He shall take from all creatures as much as nature desires and craves and shall have no scruples of conscience about it, for all created things are his property." The property included women: one of the signs of being a member of the elect was the ability to indulge in promiscuity without qualms of conscience.

The historian of this dark, prophetic tradition, Norman Cohn, in *The Pursuit of the Millennium*, also described the social conditions which bred the various movements. It was not the often starving but secure peasants who provided the raw material for the prophetic movements. It was the townspeople of the prosperous belts of Western Europe where, even in the Middle Ages, some of the features usually associated with modern industrial society were found: great inequalities of wealth, unemployment, and insecurity.

The other tradition of prophecy is more recent, the product of the last three or four centuries of scientific and economic development. It is basically optimistic, relying for its appeal not on fear but on hope. Man's history is a progression from ignorance to knowledge, from being the victim of his environment to being its master. Clearly this tradition casts the intellectual or scientist in a central role—since it is his knowledge which gives mankind its tools and his skills which allow it to steer an untroubled course into the already mapped waters of the future.

It is in this optimistic intellectual climate that futurology has flourished. It is difficult to draw a clear distinction between utopianism (an ideal future world) and futurology (a probable future world). Given sufficient optimism—and there was an abundance of it in the 18th and 19th centuries—the ideal easily shades off into the probable. Thus in 1770 Sébastien Mercier, in his *L'an 2440*, anticipated many 20th-century works of futurology by predicting a world in which man would only work for a few hours a day, and (more acutely) in which the study of classical languages would disappear and that of history be neglected, since it records "the disgrace of humanity, every page being crowded with crimes and follies." But although there was great faith in civic and intellectual progress, the emphasis on material progress—economic growth—was not to come before the second half of the 19th century; only then did the possibility of rubbing the magic lamp of technology to produce unlimited prosperity become one of the main props of social prophecy. This theme survived even the world Depression of the 20's and 30's. In 1930 John Maynard Keynes, in his essay, "Economic Possibilities for our Grandchildren," celebrated the approaching solution of the "economic problem" and announced the impending arrival of the problems of technological unemployment and leisure.

To look at the prophetic tradition historically is to realize that futurology may be revealing chiefly of the social and cultural assumptions of its authors: that one of the best guides to the preoccupations of any generation or any society may be its fears and hopes about the future. Indeed, just to glance at some recent products is to realize how quickly intellectual fashions now oscillate: man's future (if one is to believe the professional social prophets) is changing almost on a year-to-year basis. Dennis Gabor, in his unassuming but shrewd *Inventing the Future*, published in 1963, concentrated largely on following the trail laid by Keynes. He explored some of the social implications of technology and automation. In 1967 Herman Kahn and Anthony J. Wiener in their *The Year 2000** —modestly subtitled a "Framework for Speculation on the Next Thirty-Three Years"—dealt with politico-social developments but also put much emphasis on the nuclear balance and its consequences for the world military situation. Both books discussed population increases. Neither book as much as mentioned, let alone discussed, pollution, and only Gabor referred to the drain on the world's natural resources of raw materials, and that very briefly.

Now, five years later, it appears that the world's long-term future has suddenly changed. We no longer live under the shadow of nuclear war. We no longer live under the threat of enforced idleness brought about by automation. We are no longer faced by the danger of domination by an all-knowing because all-computerized bureaucracy or by a military-industrial power elite (to quote some other prophetic visions of the recent past). Instead we are told that we

* The Kahn and Wiener book, along with *Toward the Year 2000*, a report of the American Academy of Arts and Sciences' Commission on the Year 2000, is discussed in "The Year 2000 and All That," by Robert A. Nisbet, COMMENTARY, June 1968—ED.

are living in the shadow of an overpopulated, overexploited, overproducing, and overconsuming world. Tell me who your futurologist is, one is tempted to conclude, and I will tell you what your future is.

Is this too facile or cynical a view? Futurology is, after all, one of the social sciences now. It is practiced by reputable academics. It uses all the paraphernalia of science, mathematical models, and computers. This is neither the nightmare world of the medieval prophets of doom nor the inspired guesswork of dilettante essayists. To try to dismiss *The Limits to Growth* as an example of cultural fashion may therefore be a sign of an unwillingness to face up to the "predicament of mankind" (to quote the portentous title of the Club of Rome's project), evidence of moral cowardice hiding behind a parade of historical knowledge.

Hence the importance of looking at the methods used in *The Limits to Growth*. For what makes it distinctive, after all, is its claim to have found some sort of scientific basis for its social prophecies. If its recommendations had been put forward by an old gentleman with a white beard parading up and down Times Square carrying tablets of stone, no one would have paid any attention. It is because this study typifies what is very much the approach of the 70's—and is by no means the worst example of methods being applied wholesale to predict the future of industries, cities, and the world—that it is worth analyzing in detail the way in which it reaches its conclusions.

This emphasis on the *how* of futurology may seem like unnecessary pedantry. However, it is no more pedantic than asking how Roman soothsayers arrived at their prophecies. To discover that they consulted the entrails of a slaughtered ox is to put the value of their prophecies into perspective. The fact that modern social scientists tend to consult the entrails of computers hardly changes the principle of the situation. This is all the more so since the attraction of *The Limits to Growth*, the reason it has provoked so much discussion, lies in its claim to be able to put figures to its prophecies—much as in the Middle Ages prophecy tried to reinforce its credibility by naming a specific year for the coming of the Antichrist, or the end of the world. It is this which largely distinguishes it from most previous exercises of the same kind.

For although recent exercises in prediction have tended, like Kahn's and Gabor's, to prophesy rather different futures, all the specific themes of *The Limits to Growth* have predecessors. The emphasis on the need to prevent population growth goes back at least to Malthus, in 1803. The emphasis on the dangers of unlimited economic growth was contemporaneous with the first signs that mankind could even contemplate emancipation from subsistence living: "He who has enough to satisfy his wants," wrote a medieval scholar of the 14th century, "and nevertheless ceaselessly labors to acquire riches . . . all such are incited by damnable avarice, sensuality, or pride." More recently, this theme has been taken up by Galbraith and E. J. Mishan, among others. Finally, warnings about the threat to the world's resources also have a long ancestry. Interest in ecology is not an invention of the 70's: in 1949, Fairfield Osborn wrote his *Our Plundered Planet*, calling for a "complete revolution in man's point of view toward the earth's resources and toward the methods he employs in drawing upon them," as well as prophesying disaster if the exploitation of nature continued unchecked. So, all in all, no sort of originality can be claimed for any of the predictions in *The Limits to Growth*, but only for its manner of making them.

How, in fact, are these predictions made? The MIT team which produced the study devised a "world model . . . to investigate five major trends of global concern—accelerating industrialization, rapid population growth, widespread malnutrition, depletion of nonrenewable resources, and a deteriorating environment." The model, they concede modestly, is "like every other model, imperfect, oversimplified, and unfinished." However, less modestly, they announce it to be "the only formal model in existence that is truly global in scope" and "that has a time horizon longer than thirty years."

But no model is better than the assumptions on which it is based. The actual physiology of any model—the mathematical equations expressing the relationships among the different factors being analyzed which are then fed into a computer—is a matter for experts to discuss. But its flesh-and-bone structure —the facts and theories on which these relationships are based—is comprehensible by the layman. Basically the whole exercise revolves around looking at past trends and projecting them into the future, on the assumption that these trends and the interaction among them will remain unchanged. Thus, if it is found that a particular factor has been growing exponentially or geometrically, i.e., doubling itself every few years or decades, it is assumed that this will continue. Population is a case in point: it is currently doubling itself every 33 years, with the result that the present world population of 3.6 billion is expected to be 7 billion by the year 2000.

Trends, however, are not immutable. Anyone trying to carry out the same sort of exercise in population predicting in 1940, on the basis of the trend of the previous decade, would have come a cropper. Extrapolating that trend would have produced a world population of 4.4 billion by the end of the century. The same is true of the other factors in *The Limits to Growth* model. Again, predictions about the point in time at

which the world's resources of either food or raw materials will be exhausted, assume constant trends on both the demand and the supply side, a very bold assumption indeed. Anyone writing in the late 19th century, it has been pointed out, might well have argued that the production of fodder for transport animals put a limit to the growth of the United States economy. Similarly, extrapolating existing trends is an entertaining parlor game which (if one chooses one's base year carefully) can be designed to produce almost any wished-for result. It would not be too difficult to show that at the present rate of growth, by the year 2000 every new graduate student will be either an ecologist or a futurologist. It is perfectly legitimate, of course, to use the technique of extrapolating as a demonstration of what might happen, without any pretense of predicting what will happen—simply as an illustration of the kind of changes that are likely to be required to prevent present-day trends from causing possibly undesirable or disastrous consequences. And if *The Limits to Growth* were presented simply as an exercise of this kind, and no more, it would be difficult to quarrel with it.

But if it had been presented in this tentative way, it would not have gained the attention and publicity it has already attracted. As it is, the text veers disconcertingly between warning the reader against taking it too literally and then ignoring its own cautions. Thus at one point we read of "the inexorable progress of exponential growth." It is almost as though exponential growth has suddenly become the Red Dragon ravaging the earth in some apocalyptic vision. Later on, we learn that the growth curve of resource consumption "is driven by both the positive feedback loops of population growth and of capital growth." This time feedback loops appear to have taken on a life of their own like the Tyrant of the Last Days. As in Marx and other social prophets, history itself is on the march.

MORE SERIOUSLY, *The Limits to Growth* deals in aggregates: that is, global statistics about population, production, and so on. But global statistics can be actively misleading. For instance, the brute statistics of the Gross National Product (GNP) can conceal as much as they reveal. These statistics tell us the income-per-head of population. But they tell us very little else. They do not tell us how that income is distributed. They can be actively misleading about comparative standards of living. For example, a country where children under five are looked after in nursery schools would appear to have a higher standard of living than a country where they are looked after at home, since teachers' salaries are recorded in the GNP statistics but the efforts of mothers are not. Also, global GNP figures mask what may turn out to be crucial trends for the future. Thus, unless the GNP figures are broken down, it is quite possible to miss the trend in advanced industrial countries away from manufacturing and toward service industries, a development which is surely crucial for future prospects. Again, *The Limits to Growth* ignores the growth in the proportion of the GNP spent on health and education in the North American and Western European countries: trends which (if one were to use the same technique as *The Limits to Growth* does) would lead to the conclusion that soon after the year 2000 the entire population of these countries would be either in the hospital or in school.

In fact, it is tempting to go much further still in drawing up an alternative exponential vision. In place of an apocalyptic view of a globe ravaged by famine and environmental decay, it would not be too difficult to sketch out a vision of a world where the main problem was to persuade people to work in factories—where the revolt against materialism had gone so far as to produce a pot-smoking population too dozy to engage in either procreation or production. Looking at the phenomenal increase in conviction rates for pot-smoking in recent years, any schoolchild—let alone a computer—could produce the appropriate statistics to support the alternative vision. It would, of course, be an utterly absurd one. But why assume that it is any more absurd than the one sketched in *The Limits to Growth*? Arguably, it is less so. For the MIT team viewed as historic and immutable some trends which may already be changing: indeed, the whole exercise is itself part of this reaction—one of many symptoms of the current interest in ecology, the environment, and so on. If anything, then, it would be more reasonable to look at the beginnings of what might be the trends of the future than at what could conceivably be the exhausted trends of the past. (This is exactly what Kahn and Wiener did in their futurological exercise. Taking their cue from Keynes, they speculated about the possible evolution of a society where the "puritan ethic" has become "superfluous for the functioning of the economy" and as a result "the conscience-dominated character type associated with it would also tend to disappear. Parents would no longer be strongly motivated to inculcate traits such as diligence, punctuality, willingness to postpone or forgo satisfaction. . . .")

There is another oddity about *The Limits to Growth*: typically, it conveys a medieval sense of doom about the environmental plagues that are foreordained to descend on mankind unless we quickly repent and repudiate the false god of economic growth; there is no truck with technological toys like nuclear fusion or solar energy which might rescue mankind from this cruel choice; for once technology is now the wild card in the pack of cosmological poker.

Yet in sharp contrast to all this, the unspoken

assumptions built into *The Limits to Growth* reflect a quite astonishing optimism: a belief in the perfectibility of man which belongs to the heyday of 18th-century optimistic rationalism. Thus its projections assume that there will be no major world war—to kill off some of the surplus millions—in the next 130 years: in short, the book's calculations are based on the belief that, for the first time in centuries, the world will live in peace. More fundamental still, while rejecting scientific technology as the savior-to-be, the study characteristically shows an infinite and pathetic faith in mankind's social technology. It assumes that, once its warning is heeded, mankind will be able to carry out the social revolution demanded to implement its recommendations.

Is there any reason, though, for taking these recommendations any more seriously than the methods used to support them? If futurology appears to be closely related to astrology or medieval prophecy, why bother to discuss its conclusions at all? The answer is that to ignore the future implications of present-day trends is as irrational as to assume that these trends will continue unchanged. To dismiss the need for some sort of futurology—even if we repudiate the name and the excesses of some of its popularizers—is to assume that there is some cosmic self-steering mechanism which will see us right in the end.

Many personal decisions and nearly all public-policy decisions are an attempt to shape the future, using some sort of crystal ball: whether it is investing in savings for a comfortable old age (implicit in which is a prediction that state pensions will be inadequate) or investing in highways (implicit in which is a prediction that the automobile is here to stay). The trouble with this sort of instinctive futurology or prediction by hunch is that, inevitably, it does not make its assumptions explicit. And because the assumptions are not clearly spelled out, they are usually not discussed but taken for granted, although they may turn out to be unrealistic or unrealizable hopes. This sort of approach can easily slip into the Panglossian view that everything will eventually turn out for the best in the best of all possible worlds. The kind of social prophecy epitomized by *The Limits to Growth* is a reaction to this approach. It reacts by swinging in the opposite direction, and by assuming that mankind has the knowledge, will, and ability to engage in social engineering on a global scale. In doing so, it oversimplifies as much as those who reject the need for any sort of attempt to look at future options.

In fact, futurological studies are of value, provided that they are seen as sketches of one (among many) possible options. Kahn and Wiener adopted this approach in their book, where they presented a number of speculative, alternative futures. This method allows us to examine the implications of alternative policies and avoids the trap of confusing what *might* conceivably happen with predictions about what *will* happen. It also permits us to acknowledge the complexity of social engineering—to take into account that policy decisions often produce unexpected side-results—instead of forcing everything into the mold of prophetic oversimplification. In contrast, *The Limits to Growth* assumes that while the side-effects of technological change can be assumed to be harmful (in terms, for example, of increasing pollution or depleting resources of raw materials) the side-effects of social change can be assumed to be neutral or beneficial.

Take the case of population policy, where *The Limits to Growth* does little more than express the consensus of most Western opinion.* In practice, the case for limiting population—for adopting zero population growth as the object of policy—rests much more on value judgments about what makes for a tolerable life-style than on pseudo-scientific predictions. Hence, the real difficulties faced by governments in underdeveloped countries which wish to bring the birth rate down: these difficulties reflect not so much technical problems about diffusing birth-control methods as the existence of social values which put more emphasis on large families than on rising living standards.

It is not necessarily impossible to change social values: for example, in the grossly overcrowded island of Mauritius, there has been a 40 per cent fall in fertility in the last five years. However, the unfortunate paradox—from the point of view of the "global equilibrium" thesis—is that it may well be possible to limit population growth in the underdeveloped countries of the world only by inculcating precisely those values which the developed countries are being adjured to abandon; that is, by offering the prospect of ever-growing material prosperity and by preaching the importance of rising living standards and showing that birth control is the means to achieve them. Arguably, the best weapons in the battle against overpopulation are precisely those products of Western civilization—television sets, washing machines, and cars—which are often seen by the prophets (none of whom has as yet, though, abandoned detergents in favor of beating his washing with flat stones in the local stream) as undesirable luxuries, foisted upon an innocent public through the machinations of Madison Avenue advertising agents.

But introducing new ideas about the possibility of rising standards of living is rather like introducing rabbits into a new continent. Ideas also breed, and once established may prove difficult to eradicate. Why should we assume that it is possible to carry out two major social revolutions in

* See "The Population Controllers," by Samuel McCracken (May)—Ed.

the space of a few decades, first to establish a culture of material progress and then to replace it with one of non-growth? Yet this is the astonishingly naive assumption buried in the equilibrium model. A successful population-control policy could conceivably have other undesirable side-effects as well. In practice it means exploiting the revolution of rising expectations. But there can be absolutely no assurance that a population policy can by itself satisfy the expectations aroused. Prosperity achieved usually tends to fall short of prosperity hoped for. If so, it may well be that the cultural changes required in a successful population policy will also increase political instability in developing countries. Standards of living will rise as birth rates fall, but will they rise fast enough to satisfy the new-found appetite for economic growth? And if not, will the often rather fragile political structures be able to deal with the resulting discontents? Once politicians there begin to auction off promises of faster economic growth—on the Western model—will there not be increased friction, resulting perhaps in revolutions and periodic *coups d'état*? This already seems the pattern in many developing countries. It could well become accentuated.

To make this point is not to indulge in a prediction that it is bound to happen. It is simply to suggest that it could happen. Again, to say that population equilibrium could result in political and social disequilibrium is not to argue against adopting population-control policies. It is to indicate that there may be a price to pay. For there is little point in constructing a global model which ignores the possibility (it is no more) that achieving an ecological balance may cause a social imbalance. This is to leave out of account the complexity of the real world and, by doing so, to lose what is surely the real point of futurology: not to predict the future but to encourage thought and thus prepare people for the many possible and plausible eventualities.

If there is a fairly widespread consensus about the desirability of limiting the world's population—despite the lack of knowledge about all the potential consequences—there is no such agreement about the proposal for seeking to stabilize economic growth within the next two decades. Here *The Limits to Growth* crystallizes what is very much a mood of the 70's and has clothed in statistical language the emotional vocabulary of the revolt against the cult of economic growth.

This revolt was entirely predictable. The circumstances which provided the soil of the cult—the years of Depression and mass unemployment—are now part of historical folklore. For anyone under forty they are no longer part of felt experience. More important still, perhaps, it has become apparent that economic growth is no cure-all. It does not in itself guarantee an end to poverty. It does not cure racial stress and conflict. What is more, it has unpleasant side-effects: congested streets, blighted city centers, polluted lakes and rivers.

Accepting all this, it is possible to draw two quite different conclusions. The first is that the emphasis on economic growth was exaggerated, that too much was hoped for from it, and that, however desirable, its benefits must be seen alongside its debits in a complex socioeconomic balance sheet. The other is that economic growth is positively undesirable, that the damage it inflicts quite clearly outweighs the possible advantages.

The sort of ecological doomsday approach typified by *The Limits to Growth* tends to support the second view. Just as growth was once seen as the magic formula, so now non-growth replaces it: one oversimplification takes over from another in a depressing dialectic of slogans. The emphasis on repudiating worldly goods is, of course, drawing on a very deep well of Western tradition—and the final irony is perhaps that what is basically a religious impulse now feels obliged to reinforce itself with "scientific" predictions from a computer, the 20th-century version of the apocalyptic vision. But in the past the choice was seen as a personal one. It was the individual who chose to join a mendicant order of friars or give a part of his income to the poor. Now, however, the choice is presented as a communal one. It is society as a whole which is expected to take a pledge of voluntary poverty (or, more accurately, to abstain from enriching itself still further). And the sanction is not the traditional one of retribution in the next life but ecological catastrophe in this one: present affluence and future squalor, the contemporary version of visiting the sins of the fathers on the sons.

All this may seem exaggerated. The proposed "stable state" average income per head of population—$1,800 a year—is well on the comfort side of poverty. But unfortunately the habit of the social prophets of talking in global terms conceals, as usual, some of the very real problems involved. As *The Limits to Growth* coyly puts it: "A drawback of this approach is of course that—given the heterogeneity of world society, national political structure, and levels of development—the conclusions of the study, although valid for our planet as a whole, do not apply in detail to any particular country or region." Yet if they cannot be applied to "any particular country or region," it is difficult to see their usefulness, particularly in the case of something as specific as the average income of the world's inhabitants. For how is the "average" to be arrived at? Extrapolating existing trends, the world average income would indeed be about $1,800 by the year 2000 or shortly before then: however, this would range from well over $6,000 per head in North America to

less than one-tenth of that figure in Africa and Asia (which will contain two-thirds of the total population).

In short, to talk of aiming at an economic equilibrium without discussing its political and social implications, is to indulge in meaningless rhetoric. Such an equilibrium could be achieved with only two alternative sets of assumptions. The first is that, broadly speaking, the global distribution of income will remain in the future much what it is now. The other is that there will be a massive redistribution of income from the rich nations to the poor nations. It is difficult to know which is the more unrealistic.

Leaving all moral arguments aside, it is not conceivable that the developing countries would be prepared to bring their growth rate to a halt while enormous disparities remained between their standards of living and those of the advanced Western nations. So the latter would either have to tolerate continuing growth in other countries or repress it in much the same way as traditional colonial powers dealt with native rebellions. Alternatively, the Western nations would deliberately have to cut back on their own standard of living in order to lessen the gap. Just to state these implications is to suggest that the advocates of the stable state are engaging in the luxury of mental self-flagellation, publicly confessing their own sins in the sure knowledge that they will not be asked to travel along the road of repentance themselves (the religious phraseology comes naturally in discussing what is essentially a neo-religious phenomenon).

Of course it may be unfair to push the arguments of the stable-state advocates to their extremes. However, even assuming charitably that they do not really mean all that they say, assuming also that they are simply using their slogans to dramatize the case for less emphasis on economic growth rather than for total abstention, assuming finally that they realize that most of their arguments will sound like a blasphemy to two-thirds of the world's population, it is worth looking at some counter-speculations. For after all, there may be some disbenefits to non-growth, just as there are some disbenefits to growth.

Here, writing from Britain has its advantages. For Britain is not only a country which is currently enjoying the "stable state" standard of living—that is, an average income-per-head not too far away from $1,800 a year. Equally it is an example of a society which, quite involuntarily, has for the past few years had a non-growth economy (only now is the economy picking itself up from the floor where it has been for so long). What is more, it is a society which has a strong political system, a homogeneous social culture, and despite the presence of colored immigrants, no racial conflicts on the United States scale. Here, if anywhere, there should be the model of the global-equilibrium society.

But if Britain is indeed to be taken as a model, then the prospect is gloomy. The experience of Britain would suggest that a non-growth society can produce as many and as unpleasant stresses on the social and political economy as industrial growth can impose on the ecological and natural resources of the globe. The stable-state advocates argue that growth does not guarantee greater social equality or justice. But the experience of Britain shows that stagnation (even under a Labour government ideologically sympathetic to equality) is no more helpful. Resentment of continuing inequalities is compounded by resentment of unemployment and of the failure of living standards to rise. For poverty is not just relative. Rising standards can and do mean better food, better housing, and better clothes for people. And at the current British standard of living—the "standard" for the future, let it be remembered—these sorts of improvements still matter very much. Although Britain probably has better housing conditions than most Western European countries, 13 per cent of households still lack private bathrooms and 12 per cent still live in houses or flats officially classified as unfit for human habitation. More than a third of households have no refrigerator or cooling machine, 55 per cent have no car, 65 per cent have no telephone, and 70 per cent have no central heating.

By the standards of Africa and Asia these are not symptoms of deprivation. But neither are they symptoms of an over-gadgeted, over-cosseted society. More important, the experience of the 1964-70 Labour government suggests that if the aims of policy are to be to increase equality and to spend more on social services like health and education, then it is only politically possible to achieve them at a time of economic growth (which is not to suggest that economic growth in itself guarantees more radical social policies; it may be a necessary, but is certainly not a sufficient, condition). The Labour government did not manage to achieve growth, failed to secure its other aims, and was defeated at the polls. What is more, there was a noticeable crisis of confidence in the political system as such and some signs of rising social tension, as shown in the increased number of strikes.

It is, of course, possible to argue that such social stresses reflect the pains of growth and not of stagnation. This is the position of E. J. Mishan, for example, who maintains that the British people were happier and more contented in 1951 while still in the postwar era of rationing and austerity.* This, as he himself recognizes, is an unresolvable argument since no one is in a position to measure happiness and contentment. However, there are some points which need stressing. The first is that it is clearly nonsense to

* COMMENTARY, Letters from Readers, January 1972.

present the argument as though it were a straight choice between growth and non-growth. Growth in Britain, as everywhere else, has had many unpleasant effects: the destruction of old buildings and communities, pollution by noise and fume, and, possibly, the introduction of a more hectic and therefore less satisfying life-style for some people. But it is perfectly logical to concede all this to Mishan and yet to repudiate his conclusion, since equally clearly growth has brought many advantages to a great many people in Britain. The real question is whether the penalties of growth outweigh the advantages. Here it is worth stressing that the majority of the British people have repudiated the anti-growth verdict: over the past 20 years at successive general elections they have consistently voted for the party which, in their view, would deliver the fastest growth rate. It may be that the British voters are misguided about what makes them happy and contented; equally, though, it may be that they are better placed to know than Mr. Mishan. The other point that needs stressing is that the balance sheet of advantages and penalties of growth may well work out differently for different sections of a community. Thus growth tends to threaten traditional middle-class values: it is felt to be disruptive and unpleasant precisely because it turns minority privileges into majority ones—because it means crowded roads, crowded beaches, and so on.

To share these traditional values—and to fear their erosion—should not necessarily mean accepting the anti-growth argument, though. Arguably, only when the majority of a population have achieved middle-class standards of living will they also accept middle-class standards of values—and be prepared to give priority to, say, anti-pollution measures over consumer durables. In the meantime, lamenting the consequences of the popularization of prosperity begs precisely the same questions on a domestic scale as it does on the international scale. Do the anti-growth advocates assume that the existing social and economic structure of society will somehow be frozen—and that the present inequalities (which in Britain, as elsewhere, are considerable) will become happily accepted? Or do they assume a political system which insures that non-growth does not become a synonym for perpetuating existing inequalities—that economic stagnation can be reconciled with social change?

It is at this point in the argument that the advocates of global equilibrium throw up their hands in horror at the assumption that such minor political problems as the distribution of income among countries or within individual societies cannot be overcome under the threat of catastrophe. Suddenly it appears that although the technologists and scientists cannot solve the problems of increasing food yields, recycling raw materials, or stopping pollution, politicians can square the circle of reconciling everyone to the social and economic consequences of global equilibrium.

THIS, of course, is a nonsense assumption. If anything it would, on past experience, be much more plausible to make the opposite assumption: that the social consequences of trying to achieve a global equilibrium would lead to conflict, the collapse of existing political systems, and, most likely, war between societies competing for their rations of fixed resources. Even conceding that eventually it might be possible to enforce an equilibrium, the costs of doing so might well be heavier than the (in any case problematic and uncertain) costs of refusing to be panicked into taking the ecological doomsday slogans at face value.

No one can be certain that these slogans are wrong, any more than their proponents can be certain that they are right. Indeed it is probably worth taking out a collective insurance policy on their turning out to be at least partially right: by taxing polluters, by spending more on environmental preservation, and so on (all policies, it must be stressed, which are urgently desirable in themselves and worth pursuing in order to make life more pleasant here and now even if there were no threat of ultimate catastrophe). What is really wrong—alarmingly wrong—is the fact that they are slogans, and no more. Just as the 50's and 60's spawned the slogans reflecting the fear of a nuclear holocaust, so now the 70's have produced the slogans born of the fears of an ecological cataclysm, and no doubt the 80's will make their own, distinctive contribution.

It is not ignoble to be afraid of being blown up by an H-bomb, any more than it is ignoble to fear the degeneration of the physical world in which our children will live. Indeed it is right to be angry and aroused. But it is desperately important that complex problems should not be reduced to the simple symmetry required of systems analysis. This is, if anything, the final surrender to technology—to adjust our own vision of our problems to the technical necessities of feeding them into a computer. For the inevitable result is to produce an equally simple answer, whose very simplicity makes it unfit as a guide to action. To the extent that the complex interaction of economic, ecological, social, and political factors makes prediction hazardous, the best prophets are those who allow for uncertainty: who do not sell the future like a patent medicine but persuade mankind to make continual running adjustments to what, after all, is a continually changing future.

[From the Washington Post, Mar. 2, 1972]

PREDICAMENT OF MANKIND

The Limits to Growth: A REPORT FOR THE CLUB OF ROME'S PROJECT ON THE PREDICAMENT OF MANKIND, BY DONELLA H. MEADOWS, DENNIS L. MEADOWS, JØRGEN RANDERS AND WILLIAM W. BEHRENS III

(Reviewed by Allen Kneese, and Ronald Ridker)

The reviewers are staff members of Resources for the Future, Inc., a nonprofit research group studying resources and environmental problems. Dr. Kneese is director of the quality of the environment program there and Dr. Ridker is with the program of population studies. The opinions expressed in this review are entirely their own.

This book, which is likely to be widely read and highly controversial, deals with aspects of a grand theme, the predicament of mankind. It is part of a large project sponsored by The Club of Rome, an organization consisting mostly of businessmen and scientists concerned about the future of mankind, and will be the subject of a conference at the Smithsonian Institution today.

It is clear to almost everyone that man confronts multiple predicaments and that important components of them are pollution, rapid use of nonrenewable natural resources, and high rates of population growth. It is to these problems that the book devotes itself. Most of the work was done by a group at the Massachusetts Institute of Technology. In view of the recent flood of books and articles on these matters, the reviewer must ask himself whether this study provides us with a deeper understanding of the specific nature or urgency of these problems and of their possible solutions.

The book's general discussion of the population, pollution, and resources set of issues, while informative, is certainly no better than that found in a number of others. In addition it contains some factual errors. For instance, on page 151 the authors say that species after species of ocean fishes and mammals have been fished to extinction. In fact, they have not been, but the numbers of some have been reduced greatly to the point where they might possibly be vulnerable to extinction. This and similar imprecisions would hardly be worth quibbling about if overstatements were not an unfortunate characteristic of the writing of many environmentalists. Isn't the truth bad enough? Anyway, the serious reader of this literature should carry a few grains of salt with him.

The original contribution of the book would have to be in the mathematicial models it uses to analyze the consequences of exponential population and economic growth. This means geometric growth which goes 1, 2, 8, 16, etc., as contrasted with an unchanging situation or one growing arithmetically, 1, 2, 3, 4, 5 et cetera.

The MIT group, of course, neither invented the concept of exponential growth nor were they the first to try to determine its consequences for humanity. In 1826 the Rev. Thomas Malthus published his famous "An Essay on Population" in which he predicted disaster for mankind as the inevitable consequence of population growth. Population, he said, has a tendency to grow geometrically while, because of limited land, food supplies increase only arithmetically. His predictions have not, so far, been fulfilled. For the bulk of mankind, technological developments in food production have also led to exponentially increasing rates of growth in food supplies, sufficient in most countries and over most periods at least to keep up with population growth.

But the ghost of Malthus has steadily haunted some intellectuals, and there is a long line of books elaborating his basic theme. Also, many projections of the future have been made embodying exponential growth. An excellent summary of, and contribution to, this literature is found in a 1963 book by Barnett and Morse called *Scarcity and Growth* which takes little note of the work on its precursors.

Using computer simulation techniques, the authors have expanded the Malthusian thesis in two important directions. First, they try to account for the fact that all resources—minerals, energy, even air and water—as well as land, on this finite Earth, are limited in supply. And second, they concern themselves with exponential growth in demand for such resources, not just because of population growth but also because of economic growth.

Their conclusion: dramatic increases in world death rates are virtually inevitable sometime during the 21st century unless both population and economic growth come to a halt right away, or at least within the next couple of decades. If technology does not develop rapidly enough, we run out of resources; if it does develop rapidly so that substitutes and new sources of supply are found, pollution levels grow until death rates inevitably rise; if technology is applied to reduce pollution levels, the disaster will be postponed until we run out of land on which to grow sufficient food. The overall impression is one of inevitable worldwide holocaust unless drastic measures to stop population and economic growth are instituted very soon.

Does this analysis improve our understanding of the population, resources, and pollution predicaments and what to do about them? One can have serious doubts. The authors describe the feedback loop linkages (say, between pollution and death rates), which are the heart of their simulation model, in only the most general terms. Repeated references are made to mimeographed papers housed somewhere at M.I.T. Nevertheless, a look at their flow chart shows that few of these linkages are now understood in quantitative, or in some cases even directional, terms. Many of them are at such an aggregated level that they may never be understandable in a quantitative way. A simple but fundamental fact about computers is that the quality of what comes out is entirely determined by the quality of what goes in. This is the famous GIGO principle (garbage in-garbage out).

The authors recognize that their data are very weak or nonexistent and heavily qualify their numerical results. But this is meant to be a popular book whose readers are unlikely to be very sensitive to these niceties. This has already been illustrated by some of the accounts of the study appearing in the press. Authors should not be blamed for misinterpretation of their results if they are clearly presented. Except perhaps, as in this case, when a popularization is rushed into print before the underlying research on such incredibly complex matters is published and can be evaluated by the scholarly community.

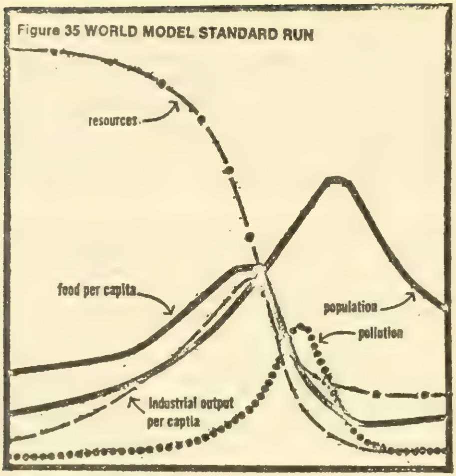
Furthermore, the authors load their case by letting some things grow exponentially and others not. Population, capital, and pollution grow exponentially in all models, but technologies for expanding resources and controlling pollution are permitted to grow, if at all, only in discrete increments.

The consequences of this can be understood by taking a look at what the authors call the standard run of the simulation model. This is meant to display the results if there are " * * * no great changes in human values nor in the functioning of the global population-capital system as it has operated for the last 100 years." In this run, population, capital, and pollution are permitted to grow exponentially while available resources are held in fixed supply—which is in fact contrary to history. The system soon collapses (it is hard to tell how soon because the time axes of the charts are only vaguely labeled) because of resource exhaustion.

But, as is clearly shown in studies like that of Barnett and Morse, new discoveries and technological improvements have, over the past 100 years, fully kept up with demand. In other words, the effectively useful resource base has been expanding exponentially too. Although it cannot be expected to do so indefinitely, it does seem reasonable that a model explicitly based on past tendencies would incorporate this. If it had, the results of the standard run would be totally different and resource scarcity would not have occurred. The assumption that resource-using activities grow exponentially and resource-expanding ones either don't grow or grow only by arithmetic increments makes the disasters projected by the model inevitable—just as they seemed to Malthus 150 years ago.

The point is that the model results are very sensitive to particular assumptions about highly uncertain and ill-defined relationships, and the uncertainty increases (probably exponentially) as the simulation rolls out into the distant future. Any reflection of reality which may be in the model soon fades away, but the computer keeps right on charting precise lines for nearly 150 years.

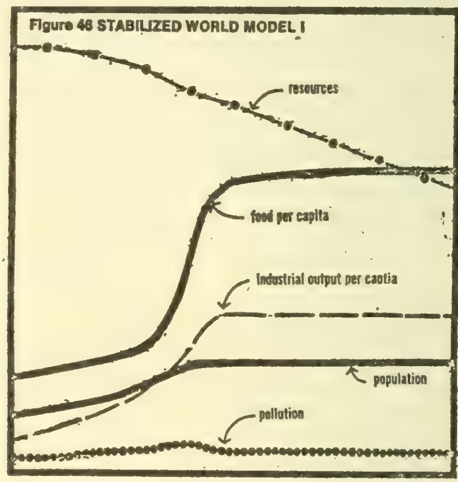
Another illustration is provided by one of their "optimistic" runs. In this, the resource base and agricultural land are regarded as indefinitely expansible (presumably through technological improvements) but the system crashes because of pollution, in what looks to be about 100 years. It crashes because it is assumed that pollution (which, like most other things, is extremely vaguely defined in the book) cannot be reduced to less than one-fourth its current amount per unit of production. So as production reaches high levels, pollution grows disastrously. The authors suggest that the reason pollution cannot be more fully curbed is that things like asbestos from brake linings are hard to control. Asbestos brake linings in a hundred years?



This standard world model run assumes no major change in the physical, economic, or social relationships that have historically governed the development of the world system. Population growth is finally halted by a rise in the death rate due to decreased food and medical services.

THE WASHINGTON POST

THURSDAY - MARCH 2, 1972
Page B 1 and 9



Charts from the book

Technological policies and growth-regulated policies are combined in this run to produce an equilibrium state sustainable far into the future. Births are set equal to deaths and industrial capital investment is equal to capital depreciation.

Projecting the specifics of technology into the remote future is a bootless chore. When we are considering events more than a few years or decades ahead, uncertainty mounts and after a while it becomes almost total. There are myriads of sensitive adjustments, such as induced innovation and substitutions of one material for another as relative prices change, which are parts of a much broader social adaptation, learning, and institution-building process. This process can be embodied only crudely, if at all, in a computer simulation. Believable theories of history are unlikely to result from a computer processing a few numerical relationships.

One can't help but believe that this failure accounts for the fact that almost all of the scenarios considered result in collapse. This is not to assert that collapse is unlikely—only that these models provide little help in understand-

ing whether it is or not, because they neglect some extremely important adjustment processes. In the very long run, these come to dominate the entire system. The more advanced economies have only recently ceased regarding air and water as free goods and to restrict or price their use. For the first time, a major scientific enterprise has gotten under way to devise efficient ways to conserve their use, and institutions for management are being built.

Nevertheless, there may be relatively firm long-term limits imposed by global changes in the chemical and physical properties of the atmosphere (say, because of the discharge of carbon dioxide). If these exist, they can only be determined by complex specialized studies we don't know how to do yet. Methodology for doing them is under active development. But the large-scale atmospheric changes which might come about, while probably on balance quite undesirable, would not necessarily lead to the kind of disastrous collapse envisaged in this book.

There also is a possibility that, any day, humanity could loose upon itself, or the ecological systems upon which it depends, a disastrously virulent substance—mercury, DDT, and PCB's gave us hints of this possibility. The proper response here is much more careful monitoring and testing than earlier—a path upon which at least the advanced countries have embarked. The global model is grandly oblivious of their problem.

The element of the human predicament that has the most momentum and the longest lag time between countermeasures and response is population growth in the developing countries. (In the United States, the population growth rate is low and falling, and in some European countries, population is not growing at all.) But we knew about the urgency of this problem already. In fact, this highly aggregated model obscures the dramatic differences between the developing and the developed world in this respect. What we don't know is what to do about it, and we get no help on this problem from global models.

Our assessment? An interesting framework upon which to hang some types of resources and environmental research? We think so. A helpful near-term tool for strengthening and deepening our understanding of man's predicament and what to do about it? We think not.

The Limits to Growth: A Critique

(*Limits to Growth*—the study sponsored by the Club of Rome[1] and conducted by a team led by Prof. Dennis Meadows at the Massachusetts Institute of Technology—was published in March 1972. Its main conclusion—that man is faced by ecological catastrophe unless zero growth rates in population and industrial production are attained by 1975—attracted great attention and controversy. Here a World Bank economist offers his views.[2]—Mahbub ul Haq)

The basis thesis in the "Limits" is a simple one—and for that very reason, it has a powerful appeal. It derives its conviction from the simple notion that infinite growth is impossible on a finite planet. It lends an air of frightening urgency to this notion by contending that the limits to growth are already being reached and that mankind is destined for catastrophe during the next 100 years unless this growth is stopped right away.

The basic thesis of the *Limits to Growth* model breaks down into the following major themes:

(1) Many critical variables in our global society—particularly population and industrial production—have been growing at a constant percentage rate so that, by now, the absolute increase each year is extremely large. Such increases will become increasingly unmanageable unless deliberate action is taken to prevent such exponential growth.

(2) However, physical resources—particularly cultivable land and nonrenewable minerals—and the Earth's capacity to "absorb" pollution are finite. Sooner or later, the exponential growth in population and industrial production will bump into this physical ceiling and, instead of staying at the ceiling, will then plunge downward with a sudden and uncontrollable decline in both population and industrial capacity.

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[1] Club of Rome.—A loose-knit group of about 75 men from 25 nations, the "club" includes eminent scientists, industrialists, economists, sociologists, and educators. Despite lack of formal budget or organizational structure, it aims to spur action on major world problems through research projects.

[2] This article is based on a World Bank analysis of *The Limits to Growth*, undertaken by a team of which the author was chairman. The author is grateful to Messrs. Nicholas Carter, Edward Hawkins, Douglas Keare, Bension Varon, Charles Weiss, and Kunniparampil Zachariah for their help.

(3) Since technological progress cannot expand all physical resources indefinitely, it would be better to establish conscious limits on our future growth rather than to let nature establish them for us in catastrophic fashion.

The authors concede that more optimistic alternative assumptions can be built into the model but they contend that this merely postpones the problem by a few decades so that it would be better to err on the side of action now rather than later. They are also conscious of some of the problems that zero growth rates may raise for the world. They hint at policies of income redistribution between the rich and the poor nations as well as within these nations; and they plead for a change in the composition of production away from industrial output and toward the social services. Unfortunately, many of the redeeming qualifications that the authors mention are not pursued by them and are generally lost in their anxiety to make their predictions as dramatic as possible.

THE BASIC ASSUMPTIONS

Any study of the "Limits" model clearly must start with a critical examination of the assumptions that went into the model of the world economy on which it is based; it is a truism that a model is just as good as the assumptions built into it. Our investigations showed that many assumptions in the model were not scientifically established and that the use of data was often careless and casual. This was particularly true of the assumptions regarding nonrenewable resources and pollution. We also found that, contrary to the protestations of the authors, the model was fairly sensitive to the choice of these assumptions, and that reasonable adjustments in the assumptions regarding population, nonrenewable resources, and pollution could postpone the predicted catastrophe by another 100 to 200 years even if one accepted the general methodology of the model. And in this context an additional 100 years might be as vital as an additional second might be to a car driver in a traffic emergency—it could transform the whole situation.

Population

The "Limits" model is right in postulating that world population has been growing exponentially in the last century and that, if the present rate of growth continues, today's population of 3.6 billion will double in the next 35 years. However, while such medium-term assumptions are fairly sound, the model does not do justice to a number of demographic factors that are likely to come into play in the long run, and which may even be significant in the short run.

To begin with, some of the recent demographic trends indicate that fertility has already started to decline in a number of countries. Of the 66 countries for which accurate data are available, as many as 56 show a decline. Most demographers are agreed by now that the 1970's will see the popultion growth rate reach a plateau so that by 1980 population growth rates will tend to decline, slowly at first and rapidly thereafter.

Furthermore, one of the major features in the population model of the "Limits" is that fertility and mortality levels are determined largely by economic factors, such as the level of industrial production and the output of services. Population growth in the "Limits" model can only be reduced by increasing per capita industrial production. This in turn increases the output of services, including education, which both permits the growth of family planning services and creates the climate for their use to be effective. Little attention is given to the possibility—considered realistic by many demographers—that population growth may be checked by family planning even at low levels of income.

No one will deny that continued population growth at the present rate is a serious matter which should engage the urgent attention of humanity. The question is not whether population growth can continue unchecked forever; it simply cannot. The real issue is how to arrest it through deliberate policies of population planning, and through technological breakthroughs in population control methods suitable for use in the poor nations.

We should not, however, play down the population problem as presented in the "Limits" model. Even if population control efforts are successful, the world will still be left with a substantial population problem in both absolute numbers and scope for future growth. The long time lags involved in demographic change insure that population growth would continue for several generations after balance had been achieved between mortality and fertility. Any prognostication about the future, therefore, must take into account the inevitability of a world population several times larger than the present 3.6 billion.

Nonrenewable Resources

A number of assumptions have been made about nonrenewable resources which turn out, on close examination, to be characterized by the same rather dramatic gloom with which "Limits" views population. The figures on reserves of nonrenewable resources generally come from the U.S. Bureau of Mines, but the Bureau warns that 80 percent of their reserve estimates have a confidence level of less than 65 percent; "Limits" ignores this important reservation. Moreover, some of the reserve estimates—particularly for the Communist countries—are extremely old or incomplete; some estimates for mainland China, for example, go back to 1913. Again, reserve estimates have been revised frequently over time and are likely to change again in our own lifetime; between 1954 and 1966, the reserve estimates for one of the largest resources, iron ore, rose by about five times. It is estimated by the Bureau of Mines that even these reserves can be doubled at a price 30 to 40 percent higher than the current price. Similarly, the reserve estimates for copper today are 3.5 times their level in 1935 and it is estimated that they could be more than doubled again if the price were three times higher. The "Limits" authors allow for such contingencies by assuming that reserves could increase by five times over the next 100 years. This assumption has appeared generous to many who have been alarmed by the sweeping prognostications of "Limits" but it is in fact extremely—and many experts would say almost irrationally—conservative.

It can, of course, be objected that reliance on such illustrations of how the world's resource base has expanded shows an unjustified and adventuresome confidence in history. However, this can no more be faulted than the use of history in the "Limits" study which only looks at the story of irrationality, waste, and neglect.

The pessimism of the assumptions on nonrenewable resources becomes even more evident if one considers that the concept of resources itself is a dynamic one: Many things become resources over time. The expansion of the last 100 years could not have been sustained without the new resources of petroleum, aluminum, and atomic energy. What are tomorrow's possibilities?

As an immediate example, there exists the imminent potential for exploiting resources on the seabed. Reserves of nodular materials—the most promising underwater source of minerals—distributed over the ocean floor are estimated at levels sufficient to sustain a mining rate of 400 million tons a year for virtually an unlimited period of time. If only 100 million tons of nodules are recovered every year—a target which appears to be within reach in the next 10 to 20 years—it would add to the annual production of copper, nickel, manganese, and cobalt to the extent of roughly one-fourth, 3 times, 6 times, and 12 times, respectively, compared to the current free world production levels. And the present production cost estimates are a fraction of current prices—one-fifth for copper, one-thirteenth for nickel, one-twenty-fourth for cobalt. These estimates—like all such estimates—are very tentative; but there is a good deal of evidence that exploitation of seabed resources is fast becoming a real possibility.

If certain resources are likely to become scarcer—or, to use the jargon of the economists, if supply inelasticities are likely to develop—it is a scientific and intellectual service to humanity to draw attention to those resources and to the time period over which they may vanish, given current usage and the present state of knowledge. Research into these areas is, therefore, both useful and vital. But it is quite another thing to argue that no amount of research, no technological breakthroughs, will extend the lifetime of these resources indefinitely or to pretend that supply inelasticities will afflict all natural resources in the same manner and at the same time in an aggregate model. While identification of specific supply inelasticities in advance of time is a definite service, sweeping generalizations about complete disappearance of all nonrenewable resources at a particular point of time in the future is mere intellectual fantasy.

It should also be remembered that the waste of natural resources is a function of both their seeming abundance and of public attitudes. It is quite possible—and indeed probable—that with either of the above factors changing, resources can be conserved without undue pain. For the major flaw of today's pattern of consumption is not really that we consume too many final goods and services, but that we use our resource inputs extremely inefficiently. If certain resources become more scarce and their relative price increases, there will be a powerful incentive for their more efficient use—a factor that "Limits" completely ignores, as it ignores similarly potent positive factors throughout. For instance, energy can be much more economically used. There is scope for smaller cars with weaker

engines, public rather than private transport, increasing efficiency in burning fuels and in generating and distributing electricity, and improved design of aircraft engines and bodies.

Looking at the problem, as *Limits to Growth* has done, in terms of quantifying the life expectancy of resources as presently constituted, we conclude that these are sufficient to last very much longer than stipulated. It is not a question of expecting natural resources to accommodate forever our current patterns of growth, production, and consumption; clearly, they will not. But we are confident that natural resources will last long enough to allow us time to make deliberate adjustments in the way we use them so that resource needs can be met indefinitely. We have seen no convincing evidence to suggest that mankind faces a final curtain about 100 years from now through depletion of nonrenewable resources.

ABOUT 80 TO 90 PERCENT OF PRESENT POLLUTION CAN BE REMOVED AT RELATIVELY LOW COST

Pollution

The assumptions regarding pollution are the weakest part of the model of world economic activity on which Limits is based. In many instances they are not established on any scientific basis. We still know so little about the generation and absorption of pollution, and about the effects of pollution, that definite functions are very hard to establish.

Our examination of the relationships between pollution and economic growth began with a study of the model developed in the book *World Dynamics*.[3] We did this because the Limits model was not available to us at that time. This indirect examination was justified because the Limits model treats pollution in much the same way that World Dynamics does. The main differences are that Limits allows for a time lag between the generation of pollution and its effects and also for pollution resulting from agricultural development. However, these differences are hardly important for the main argument of the Limits model.

Although little is known about the generation of pollution, it is simply claimed in the World Dynamics model that it rises at the same speed as the growth in capital stock per capita. As natural resources are used, progressively more capital must be applied to extract a given amount of final outut—because of the necessity of using increasing amounts of energy in production as resources are either consumed or disposed of. Hence pollution grows to increasingly higher levels. In fact, the prediction of a pollution catastrophe depends on the value of the ratio assumed in the model between the pollution level and capital stock per capita. It appears from our study, however, that if the assumed value could be reduced by five-eighths—an adjustment well within the error range of the data—the prediction of catastrophe would be completely erased. Since data on actual relationships between pollution and capital stock are sparse, there is no particular reason to favor one value for the ratio rather than another.

Again, in discussing the Earth's capacity to absorb pollutants, the World Dynamics model assumes, entirely arbitrarily, that the world's overall capacity to absorb pollution is four times the present annual level and that pollution levels beyond certain limits will start affecting human mortality. While it may be true that accumulating pollution levels may destroy present concepts of living during the next 100 years, there is little evidence that life itself will be destroyed.

Furthermore, the authors do not fully consider that higher levels of industrial development will allow societies to devote additional resources to taking care of the pollution problem without sacrificing continued economic growth. It has been estimated, for example, that the United States could spend $16 billion a year, or about one-third the annual increase in its gross national product, and achieve a substantial reduction in pollution over the next 6 years. Despite this, the United States could still increase its per capita consumption by another $900 over this period. Similarly, it has been calculated that about 80 to 90 percent of present pollution can be removed at a relatively low cost: The cost increases would be about 5 percent for industrial waste; 2 percent for thermal electricity; and 10 percent for automobiles.

Despite such objections to the Limits model, it should not be thought that pollution is of little global concern or that it is unrelated to economic growth. It is simply that information of the kind given above—which is extremely pertinent to the Limits projections—illustrates that pollution buildup and world collapse is not necessarily inevitable even with continued economic growth.

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[3] Jay W. Forrester, *World Dynamics* (Cambridge, Mass., U.S.A., 1971), Wright-Allen Press.

In general, however, the assumptions of the model regarding population, depletion of nonrenewable resources, and pollution and absorption should not be taken lightly. However, more study and research is needed to establish more reasonable parameters for those three critical variables in a long-term model.

NATURE OF THE MODEL

From an analysis of the basic assumptions of the model, we turned to its essential nature and methodology. Here we found that our analysis was handicapped by the extreme aggregation found in the model. The whole world is treated as one and homogenous even when it is clear that the real world is characterized by vast differences in income and consumption patterns: for instance, the per capita income levels in developed countries are 14 times those in the developing countries; and the style of development, the patterns of growth, and the composition of consumption demand vary widely in different parts of the world.

The highly aggregate nature of the model raises a number of difficulties in analysis. For one thing, it is not clear how seriously one can take averages of various variables which are widely dissimilar. For another, it makes any plausible interpretation of the model very difficult. There is only one aggregate natural resource or one aggregate pollutant, keeping one guessing as to how representative its behavior is of the real world which is marked by much greater diversity, complexity and substitutability.

More important, it is not possible to get any useful policy guidance from such an aggregate view of the world. The real world is divided politically into a number of nation states and economically into developed and developing countries. They do not all behave similarly nor are they affected in the same manner. Thus, if natural resources are being progressively depleted, this may raise their price and benefit the producing countries which are mostly in the developing world. The transfer of resources from the rich to the poor nations in such a situation may well alter the overall pattern of growth rates. Such natural checks and balances arise in the real world but they are not allowed for in the Limits aggregate world model which moves only in one direction—toward disaster.

Before we can arrive at any useful or relevant conclusion, a minimum condition is to construct at least a two-world model, distinguishing between the developed and the developing world. Without a greater degree of disaggregation there is a great danger that the model may become a caricature of the real world rather than a mere abstraction.

The methodology used in the model further helps us along the road to disaster. It does not allow for economic costs and prices nor for conscious choices made by society; there are no real corrective mechanisms—only physical engineering relationship. The world keeps on proceeding in its merry way—frittering away its resources, populating itself endlessly, accumulating pollution—until one fine morning it hits disaster.

Is this a realistic abstraction from the world as we know it? In the real world, there is not one nonrenewable resource but many. They do not suddenly disappear collectively but become more and more scarce individually. As each resource becomes more scarce, price signals flash and alarm bells ring all over the world. This directs technological research into them; possibilities of substitution are explored; conscious choices are made by society to economize on them, to do without them, or to enlarge their exploitation by using marginal reserves or by recyling at a higher price. In other words, corrective mechanisms start working. Similarly, it is hard to believe that a pollution crisis can sneak upon humanity as insidiously as the model implies. Even a modest level of pollution would mean that even though the world average of persistent pollutants was still quite low and not yet obnoxious to human health, some particular localities would be suffering to a point at which corrective action would have to be taken—London, for example, introduced legislation to help purify its air and eliminate the deadly "pea soup" fogs.

Humanity faces these problems one by one, every year in every era, and keeps making its quiet adjustments. It does not keep accumulating them indefinitely until they make catastrophe inevitable. One does not have to believe in the invisible hand to subscribe to such a view of society. One has merely to believe in human sanity and its instinct for self-preservation. While the model itself contains hardly any mention of conscious corrective mechanisms, in a larger sense its very appearance can be regarded as part of the corrective mechanism which societies devise in response to major problems.

One of the most curious parts of the model is its treatment of the role of technology. In an age of the most dramatic technological progress, the authors

contend that there cannot be a continuation of such rapid progress in the future. And this is merely an assumption, not a proven thesis. The model assumes that certain things in this world—population, capital stock, pollution—will grow at exponential rates; but it assumes that certain other things—specifically technology to enlarge the resource base and to fight pollution—will not grow exponentially. Any such model is inherently unstable and we should not be surprised if it leads to disaster.

The authors' assumptions are, however, scarcely realistic since man so far has continuously proved his ability to extend the physical limits of this planet through constant innovations and technological progress. There is no reason to think that technological innovations in conserving, recycling, and discovering new resources, and in combating pollution will stop simply because by their very nature we cannot predict them in advance.

Policy implications of the model

The policy implications which flow from the "Limits" model are the least stressed and the least developed part of the book. Yet, it is these policy implications that have attracted the greatest attention since the book has appeared. The major policy conclusion from the model is the prescription of a zero growth rate, both in population and in material production. But that prescription is not logically derived from the model. Even if one accepts some of the premises of the authors about certain physical limits to further unchecked growth, it is not clear from their work why the world must immediately move in 1975 to zero growth rate. Since the model excessively aggregated, the authors are in no position to discuss various alternative choices which are still open to society even if physical limits to growth are conceded.

There is first the choice between development and defense. Presently, about $200 billion is being spent on defense, which is one of the major users of world resources and generators of pollution. If society is really concerned about resource constraints, could it not consciously choose to devote less resources to defense and more to development? Again, there is the choice of patterns of growth. If natural resources become more scarce, could society not decide to have a different pattern of consumption—based on more services and leisure—which is less resource consuming? Finally, if the rich nations were to stop growing, the growth of the developing world could well proceed without putting major pressures on global physical limits, whatever these may be. These are some of the real choices that humanity faces at present and a good deal of debate is centering on them. But these choices can hardly be considered in the context of the "Limits" model which is sweeping in its overall policy prescriptions.

Another area of policy concern is world income distribution. If we were to accept, as the authors do, the thesis that the world cannot be saved except through zero growth rates, we must also demonstrate that world income redistribution on a massive scale is possible. Otherwise, freezing the present world income distribution would not save the world; it would only bring about a confrontation between the haves and the have-nots. "Limits" recognizes this but skips the issue rather lightly as if it were a mere irritant. It does not address itself to the basic issue; how is such a redistribution to be brought about in a stagnant world? Through negative growth rates in the developed world and positive growth rates in the developing countries? Through a mass immigration of the populations of the developing countries into the developed world? Through a massive transfer of resources under a world income tax? And what is the realism of all this in a world that is rather reluctant to transfer even 1 percent of its gross national product in the form of development assistance? While income redistribution is a desirable objective and must be pursued with full vigor, we must recognize that it is going to be even more difficult to achieve—both within and between nations—if there is no prospect of future growth and various groups fight to keep their share in a stagnant world.

The basic weakness of the *Limits to Growth* thesis is not so much that it is alarmist but that it is complacent. It is alarmist about the physical limits which may in practice be extended by continued technological progress, but complacent about the social and political problems which its own prescriptions would only exacerbate. Yet it is such problems which are probably the most serious obstacles in the way of enjoyment of the Earth's resources by all its population. The industrialized countries may be able to accept a target of zero growth as a disagreeable, yet perhaps morally bracing, regime for their own citi-

zens. For the developing world, however, zero growth offers only a prospect of despair and world income redistribution is merely a wistful dream.

The shock waves generated by the "Limits" will do good if they start some serious academic work on the long-range issues of global survival. To the extent that they divert effort from the grave but probably soluble problems of our own day to plans for dealing with specters in the future, they can only do harm.

The Limits to Growth

(By Donella H. Meadows, Dennis L. Meadows, Jergen Randers, William W. Behrens III)

[Published in the United States of America in 1972 by Universe Books]

The continuing debate over the last few years about whether the contributions of science to civilization is on balance a good thing is more tedious than it is inconclusive. In any case the proponents of more science almost invariably cheat. Apparent successes over the past are clearly evidence in favor. Apparent failures to solve problems—even problems created by science and technology—are grouped under the category of "challenges." [1] Using this lamentable methodology the technocrat, of course, cannot lose. If scientific benefits can't be discerned, the efforts of scientists are fruitful, and should obviously be encouraged. If disasters result, there is surely an urgent case for more scientific research. It is not too surprising that ecologists occasionally employ the same sort of forensics. Disasters attributable to the results of scientific research speak for themselves. As for current scientific achievements, in a highly complex ecosystem, interference is sure, sooner or later, to produce some ecological calamity.

The public, too, is beginning to tire of comparing the relative demerits of smog in London 20 years ago and of carbon monoxide and lead poisoning today; of comparing the disappearance of some bird species and the reappearance in the Thames of some (possibly mutant) fish; of comparing poverty today and of poverty 50 or 100 years ago, and of comparing crime, mortality, and disease, then and now. For the salient fact today is that the ecological problem, if not the social problem also, has become global. Nobody any longer can get away. The air, the land, the waters of the Earth are indeed being polluted by man on a scale, and at a rate, that is quite unprecedented in history. Never before did man produce thousands of synthetic compounds each year—the long-term consequences of which, singly or in combination, as it happens, we know next to nothing about. Never before have men lived under the threat of nuclear annihilation or of extinction in any number of horrible ways by biochemical means of warfare. Never before was population so large, so interdependent and so vulnerable. And never have resources been consumed on so stupendous a scale.

Any regard to perspective, understandably breeds an impatience with these perpetual debates about the history of local disamenities. A global approach is sought; a general model capable of handling a select number of critical variables: a model into which data can be fed and from which (hopefully) will emerge vital information about the course of future events.

The *Limits to Growth* is a popular account of such a model—one that, perforce, ignores the risks of warfare, diseases, or sudden ecological collapse. With a high degree of confidence, one can predict that the book will not be welcomed by economists. Since very few of them have seriously questioned the notion of sustained economic growth as a legitimate aim of social policy—indeed the accent since the war has been on ways and means of increasing rates of economic growth—the greater the success of reports such as these in persuading the public of the sheer physical impossibility of continuing much longer along the growth path, the greater the damage to the credibility of economists habitually regarded as the custodians of society's material well-being. Indeed, generalizing from the response to the *Blueprint for Survival* in this country, even the sort of denunciation it will invoke can be anticipated. Ritual scorn will be poured on doomsayers. Prophecies of world catastrophe reaching back to ancient Egypt will be unearthed. Yet again will Malthus be dismissed as a false prophet. The economists will hasten to remind us that as traditional resources become ex-

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[1] For a recent and quite typical example of this method of argumentation, see the short article by Kenneth Mellanby, "Ecologists Who Ignore Technology's Successes," which appeared in The Times, Mar. 3, 1972.

hausted, new materials are sure to come into being, and new technologies should enable us continuously to raise real standards, at least in the West. For the boundaries of science are widening today more rapidly than in any other period in history. Not least, economists will insist that the model described in the book is far too simple to express reality, and that it makes no provision for the resource and ingenuity of man.

And yet this book is sure to make an impact, as indeed did the Blueprint which preceded it by a couple of months. It comes at a time when Western societies are beginning to experience a growing variety of environmental ills; at a time when alarm is mounting at the unabating growth of the number of inhabitants on this seemingly tiny planet; and at a time of increasing public awareness and exasperation at the apparently inescapable noise and traffic pollution, at the rising levels of toxic substances in the air and seas, and at the growth of lawfulnesses and disruption. A loss of confidence about our way of life has set in. People are seeking a new ethic and a new ethos.

After illustrating and emphasizing two particular features—the incredible magnitudes that eventually result from continued compounding, and the interconnection of key variable such as food production, industrial output, population, resource consumption, and pollution—the authors, who adopt the method of investigation pioneered by Jay Forrester, discuss their findings. In terms of timepaths of the above variables, these findings tend to the conclusion that growth, whether of population alone, or of per capita output alone, just cannot continue for more than about a century. If, to take the simplest case, we attempt to continue as we have been doing over the past few decades, rapidly diminishing resources will entail a decline both in industrial output per capita and food output per capita in less than a hundred years. Pollution will begin to decline some years later, following which event the rise in population will be reversed by a climbing death rate. Controlling population alone, while attempting to maintain the growth of per capita output cannot succeed either, because of an eventual shortage of resources and because of increasing pollution levels. If new resources are found, if pollution-reducing devices are discovered, this extends the period of grace by some 10 or 20 years, but not much longer. Survival over the indefinite future apparently requires not only stabilizing the population and industrial capacity, but also reducing pollution and reducing resource use per unit of industrial output through recycling of resources, more efficient technology, and a shift from products to services.

The model used, though simple in the sense that it confines itself to the timepaths of a few key variables is relatively complex in structure. The mathematical equations describing the links between the variables cannot, of course, be laid bare in a popular account, and the general reader has to be content with some simple illustrations, verbal and diagrammatic, of the nature of the interconnections and, later on in the book, with descriptions and graphs (not as clearly drawn as they might be) of the timepaths of the variables that emerge from the computer in response to altering initial assumptions and parameters. What the more serious critic will want to examine, however, is not only the information fed into the model, but the structure of the equation system. Do changes in the structure of the equation system make significant differences to the results? For all that, a beginning has been made. A global model has been made explicit and, therefore, open to modification and further experiment and refinement.

Once they have vented their spleen and ventilated their cynicism, economists are almost sure to start fiddling about with this sort of model. Indeed, they will find it hard to resist, since by training they are habituated to think in terms of interdepedent systems, of timepaths and adjustment mechanisms. One of the questions they might want to formulate, and which is not formulated in this report, is—given, say, population stability—what sustained rate of advance of technological innovation, measured say in such terms as resource and pollution reduction per unit of output, would be required to maintain over time any given positive per capita growth. Certainly it would be salutary for growthmen and antigrowthmen to have some clearer ideas of the magnitude of the tehnical achievements that are needed over time if positive growth rates are to be maintained. If such ideas can be quantiatively formulated, and if it transpires that they fall short of any reasonable expectation, the revolution in thought necessary to induce peoples and governments to acknowlege the limits on man's powers to bend nature to his will can begin to occur, and we shall start thinking about the future in all earnest.

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GROWTH AND SURVIVAL

By Robert L. Heilbroner

LIFE on this planet is a fragile affair, a kind of miraculous microbial activity that flourishes on the thin film of air and water and decomposed rock which separates the uninhabitable core of the earth from the void of space. Over most of mankind's history, the existence of that environment has always been taken for granted, and human efforts have been devoted to "taming" it—that is, to altering that vital film in various ways to assure our easier survival. Now, with stunning suddenness we have come to the realization that the environment is not to be taken for granted after all—indeed that it may be on the verge of an irremediable deterioration. For if the calculations of a group of social and physical scientists are correct, it will take only another 50 years of population growth and economic expansion at present rates to cause a collapse of our life-supporting ambient, bringing mass famine in some areas, industrial breakdown in others, a drastic shortening of lifespans nearly everywhere.

This terrifying scenario stems primarily from the work of Jay Forrester and a team of scientists at M.I.T. who have projected, by means of computerized models, the complex interactions of human activity and the environment. The models form the basis for two clarion calls for an immediate halt to the destruction of the environment—"A Blueprint for Survival,"[1] signed by some 30 eminent British scientists, and a much touted and widely circulated book, "The Limits to Growth,"[2] sponsored by The Club of Rome, an international "invisible college" of 70 scientists and specialists. Essentially, both studies tell us the same thing—that if we are to preserve the life-supporting capabilities of our all-important film of air, water and soil, economic growth must be brought to a halt as rapidly as possible. For the projections on which the two studies rest show that even if population growth halts within two generations, even if we discover "unlimited" new resources, and even if we remove three-quarters of the pollution we generate, continued industrial growth by itself will

[1] "A Blueprint for Survival," *The Ecologist*, January 1972.

[2] "The Limits to Growth," by D. H. Meadows, D. L. Meadows, J. Randers and W. W. Behrens III. New York: Universe Books (A Potomac Associates Book), 1972.

still bring us to a condition of "self-destruct" within the lifetimes of our grandchildren. Well before the year 2100, the population of the earth would then begin a period of decline as dramatic as that of Europe during the Black Death, but unhappily by no means so short in duration.

This is a projection so overwhelming in magnitude that it is difficult to confront it with any sense of detachment and balanced appraisal. Indeed, rather than detachment, the need of the hour seems to be a call to arms—or rather, to the crash program described by the scientists of the "Blueprint" and the "Limits." Yet, in full recognition of the gravity of the situation, I would propose a different course. In the end, the scenario that I project is no less sobering than that of the anti-growth school, but, as we shall see, it leads to a very different strategy for our times.

II

Let me begin by recapitulating very succinctly some of the trends and facts that have led to the recent impassioned call for a halt to economic growth. The first of these is by now so familiar that it may have lost its power to shock, but it must nevertheless be our starting point. This is the fearsome growth of population, increasing at a rate that doubles every 30 years. Today estimated at 3.5 billion, world population is pressing toward the level of 28 billion less than a century hence—I say "pressing," since no estimate that I have seen envisages increases in food production within that time span sufficient to feed such a multitude.

Of course, this neglects the potential braking effect of birth control. There is a growing consensus that demographic increase can be brought to a halt in the industrialized nations by the year 2000; and there is the possibility that net reproduction rates can be brought to zero in the underdeveloped world (where population is still doubling every 18 to 20 years) within two generations. Unhappily, because so much of the population in these areas is under child-bearing age, even a drop to zero net reproduction rates—approximately one female child per married couple—will not bring *total* population growth in these areas to zero, as larger and larger "cohorts" of children will continue to reach the age of fertility for some time. At best, then, demographers estimate that we will "only" have to cope with a global population of 15 billion by the year 2060. In fact, the number may be much larger.

The population explosion brings us to the physical problems of the carrying capacity of the earth—I shall leave unmentioned such essentially social problems as cancerous urban growth or the psychological effects of overcrowding. The first of these physical problems is that we will simply run out of the resources required to maintain the present pace of industrial expansion. Curiously, this is not a problem that is immediately connected with population growth, for the great bulk of industrial activity in the world is concentrated in the advanced areas where the demographic problem is least severe. Industrial expansion in the advanced nations is today growing at a rate of about seven percent a year—a rate that doubles total output every ten years. If we therefore look ahead 50 years, it is probable that industrial output, using existing techniques, will have increased by the *exponential* number of five—doubling in 10 years, quadrupling in 20, octupling in 30, etc. Anyone familiar with the power of compound interest will recognize this curve as one whose upward slope becomes ever steeper.

Can we feed the industrial megamachine that these projections indicate? The table below, on which the anti-growth school bases its case, indicates that we cannot.

GLOBAL RESOURCE AVAILABILITY[3]

Resource	*Years available at present growth rates*	*Years available if resources are quintupled*
Aluminum	31	55
Coal	111	150
Copper	21	48
Iron	93	173
Lead	21	64
Manganese	46	94
Natural Gas	22	49
Petroleum	20	50
Silver	13	42
Tin	15	61
Tungsten	28	72

The table (based in the main on estimates of the U.S. Bureau of Mines) makes two formidable points. First, according to existing estimates, there are not enough resources to allow industrial expansion to continue unhindered at a compound rate of seven percent a year for anything like 50 years—much less a century—with the exception of a few items such as coal or iron. Long before then, the exhaustion of first one and then another

[3] "The Limits to Growth," p. 56–59.

critical resource would have effectively brought the trajectory of growth to a halt. Thereafter, the M.I.T. computerized models show industrial output abruptly entering a period of steep and prolonged decline.

Second, the table reveals that even very large increases in resource discovery, such as the five-fold enlargement shown in the column at the right, add only disconcertingly small increments of time over which exponentially growing industrial output can be maintained. As we shall see, the problem of the astonishing rapidity with which an exponential series reaches any given finite limit appears again and again in the environmentalists' drama. So far as resources are concerned, this fact contains an important warning against expecting too much from the possibility of recycling scarce materials which, like the discovery of new resources, only adds a finite increment of new resources.

An even more serious aspect of the industrial growth problem is the capacity of the earth, not to yield up the needed resources, but to absorb the residues and wastes, the harmful products and by-products of industrial production—in a word, its ability to withstand the effects of pollution. "Pollution" is a word that covers many kinds of unwanted direct or side-effects of economic activity. There are pollutants that are nuisances, such as noise pollution or littering, and pollution that is local in extent—Lake Erie may be "dead," but its corpse is confined within its geographic boundaries. On the other hand there is pollution that is deadly, such as radiation, and pollution that is globally diffused —for example, lead spewed into the air by American and European cars has shown up over the last 30 years in a three-fold increase in the amount of lead in the Greenland icecap.

It is the second class of pollutants on which the environmental scientists focus their attention. Many examples of it have become familiar, although no less frightening for that reason. A now famous claim is that most mother's milk in the United States contains so much DDT that it would be declared illegal in interstate commerce if it were sold as is cow's milk. Less widely publicized, but of no less significance, are the effects of nitrates and phosphates deposited in the soil by chemical fertilizers. Nitrates, in particular, enter the water supply and are then converted within the human body into nitrites, which cause infant mortality. Chemical fertilizers also cause soil leaching and lead to eutrophication of the bodies of water into which they drain,

bringing about huge algae "blooms" and the death of large marine populations.

Central to the argument against economic growth is that these deadly and globally diffused pollutants are also increasing exponentially, along with, and as a direct result of, exponential industrial growth. We shall have a chance later to examine some of the presumptions on which this contention rests. But there is no doubt that pollution is ultimately the mortal enemy in the eyes of the anti-growth school. For there are certain kinds of pollution that cannot be avoided, short of the most far-reaching changes in our industrial technology, and one kind that cannot be avoided by any known or imagined technology.

In the first class lies the polluting effect of the process of combustion, the central source of power throughout the world today. Combustion is a term that describes the conversion of oxygen into carbon dioxide in the process of "burning." As a result of the massive burning by which the industrial mechanism is kept operative (not to mention that which supplies heat for our homes), the amount of CO_2 in the atmosphere is steadily rising. Extrapolating from present trends, we can predict that it will increase by some 30 percent during the next 30 years. Scientists are uncertain but uneasy about the effects of this altered composition in changing the vital heat-trapping properties of the atmosphere. Over the longer run, they fear as well the slow exhaustion of the oxygen supply itself. Today the United States already consumes more oxygen than its green cover can regenerate. This is a process that can continue for a very long time, but not forever—especially if the entire world were to attain U.S. levels of combustion per capita.

Even more portentous is the problem of the production of heat. Inherent in the production of energy in any form is the generation of heat. Professors Pirages and Ehrlich have recently warned that the use of energy on an American per capita scale for the 750 million who today occupy mainland China would release heat in certain areas that could lead to "major, unpredictable effects" in climatic patterns. If we scale up this warning to take into account the 15 billion who may inhabit the earth in another three generations, we are forced to contemplate the possibility that an American standard of heat-generation at these population levels might bring an environmental disaster comparable to the onset of the Ice Ages.

III

In the face of these overwhelming facts, that sense of detachment and balance of which I spoke earlier is not easy to achieve. It may be helpful to begin, therefore, by considering growth from another point of view—paying no heed for a moment to its destructive effects and emphasizing instead its constructive implications.

This brings us back to the population explosion that provided our initial point of entry into the ecological problem. Given the minimum figure of 15 billion a century hence, we confront a human problem that immediately places growth in a wholly new perspective. For it makes clear that any effort to strive for zero growth in industrial output today would, in effect, be a decision to deprive the forthcoming population of its ability to subsist. Such a decision might impose a very rapid "solution" to the population problem, but it would be the solution of starvation. Moreover, since most of the prospective population of the coming generations will be crowded into the underdeveloped areas, the forecast also makes it clear that growth in industrial output in those areas must take place *faster* than population, if the billions who are to be born in those regions can ever attain a standard of living better than that which they now "enjoy." At least some indication of the magnitude of this required increase can be gained in comparing the GNP per capita of Portugal—hardly a nation known for her high material standard of life—with that of the backward regions. In 1966, GNP per capita in Portugal was $529; in East and Southeast Asia (excluding Japan) it was $114; in sub-Saharan Africa (excluding Rhodesia and the Union of South Africa) under $100. Thus if the poorest two-thirds of the world's prospective population are not merely to subsist, but to make an ascent to the level of a Portuguese peasant, output in the backward lands will have to rise about 12- to 15-fold—first to accommodate a probable three-fold increase in sheer numbers, then another four- or five-fold to supply each of these new inhabitants with an income on a Portuguese scale.

Admittedly, figures such as these must be treated with great caution. Gross national product is a very inadequate indicator of human well-being. In many of the backward lands important improvements could be made in the quality of life merely by the attainment of stable and just governments and economic sys-

tems, the introduction of literacy, the vigorous promotion of public health measures including birth control and the repair of nutritional deficiencies. These changes are not likely to be reflected in changes in GNP to the extent that increases in steel production would be, even though their importance may be incomparably greater and their demands on the environment incomparably less. Therefore the need for growth in living standards must not be assumed inevitably to require environmental damage.

Yet, with all these caveats, the fact of a relentless burgeoning of populations—and the hope for a rise in their material consumption—makes inevitable the need for very large increases in physical output. Huge additions to food production, textile output and simple shelters will be required to sustain, much less elevate, the prospective billions in the backward world. In turn this requires the output of vast quantities of fertilizer, of steel, of cement and bricks and lumber, with all the environmental problems we have seen. That vast—although somewhat indeterminate—increase in needed output provides a powerful incentive to rethink the desirability of "zero industrial growth."

Now let us add to it the demands for growth stemming from the industrialized world. We may be tempted, of course, to dispute the moral value of much of this growth. Do we need more luxury goods per capita? Would not our own quality of life be vastly improved by increases in nonmaterial "outputs," or by the redistribution of what we already possess? However valid these queries, they are as irrelevant to the problem of the environmental challenge as questions regarding the "morality" of the projected population increases in the East and South. What we are interested in, both with regard to population and industrial output, are the levels to which the world will be "pressing" under the enormous inertia of its present social forces. Any realistic appraisal tells us that just as there will be vast increases in population if that population can be kept alive, so there will be vast increases in industrial output if that output is attainable. The question, then, is whether we have the resources and the absorptive capacity to allow that mounting trend of industrial output to materialize.

This returns us to the question of basic resources whose alarming limitations we have already noted. Do those limitations mean that potential industrial growth will be throttled by resource

exhaustion, just as potential population growth may be curbed by food exhaustion?

Before we leap to that gloomy conclusion, we must reëxamine the table itself—or rather, the facts on which the table rests. Here the first important consideration is that those "facts"—the basic data of resource availability—are very insecure. With the possible exception of a few items (such as natural gas within U.S. continental boundaries), we have only the haziest knowledge of the full extent of the resources of the world. Indeed, the fact that for the past many decades each generation has ended its period of growth with larger amounts of "proved" reserves of many resources than it started with suggests that the size of our "known" reserves is mainly determined by the effort we invest in looking for them. In the Soviet Union, for example, the huge Siberian subcontinent has barely been prospected: one Russian economist recently estimated offhandedly that it contained the wherewithal for "a thousand years" of Russian resource needs. So, too, the South American continent is still largely terra incognita, and may reveal as much totally unexpected wealth as did, for example, the rich Alaskan oil slope or the Libyan oil fields, both vast reservoirs which have been discovered only in the last decade. Thus an "optimistic" estimate of the availability of resources may in reality not be five times the present estimates, but ten or 50 times. This does not rescue the world from the problem of exponential growth per capita, but it defers the day of reckoning by another generation or two.

Second, it is necessary to take into account a technological reality that the table cannot reflect. This is the substitutability that exists among resources. For instance, there is a strong likelihood that we will use up our reservoirs of natural gas and petroleum in another generation. However, the table does not show (nor do the anti-growth scientists discuss) the possibility of shifting to alternative sources of fossil fuel, such as the enormous reserves of oil shale the world possesses. By way of analogy we should recall that today we feed our steel industry with low grade ores that fifty years ago, when the Mesabi Range was still yielding its high-grade ores, were not even considered as potential "reserves." Thus, resource substitution also defers the day of reckoning by an indeterminate, but possibly quite substantial, period.

That pushing-back of the time frontier is all-important with

regard to the resource problem. For potentially the globe *has* limitless resources—limitless, at least, in reference to the needs of its microbial surface—in the minerals locked into its rocks and sea water. Given enough power, which nuclear energy now begins to promise us, we could literally "melt" the rocks and reconstitute any substance by synthetic processes. To be sure, such processes would entail the processing of enormous quantities of seawater or granite, with associated problems of disposal and thermal pollution. But from the point of view of sheer bottlenecks of supply, the long-term future holds out much more promise than the anti-growth school of thought reveals.

The basic question, then, when we consider the ultimate resources of seawater and granite, is how long it will take us to achieve the power and the techniques needed to bring these alchemic possibilities into actuality. I do not know what time scales are to be attached to these objectives, but on the answers will depend the rate at which we can safely use up "raw" materials before we switch to synthetic ones.

If the scientific consensus is that fusion power is improbable (we know it is not impossible) for an "indefinite" period, we shall have to reconcile ourselves to the scale of resource use that is compatible with fission power. If our scientists agree that certain problems of synthetic chemistry will take us "generations" to solve, then we shall have to husband carefully those substances whose supplies will be limited to the amounts we can recycle each year from our industrial process. Thus the resource problem hinges finally on our scientific and technological capabilities. Judging by the past it would be foolish to take an attitude of determined pessimism before these capabilities. For if there is one factor that ultimately limits our growth from the input side, it is our reservoir of knowledge of science and technology, and the exponential curve of that resource soars steadily upward without sign of limit.

But what about barriers imposed by pollutants? Here, as I have said, are the most serious of the limits to growth put forth by the M.I.T. studies. Yet there is a certain arbitrariness in their treatment of pollutants. The models showing "collapse" in 50 to 100 years make the "generous" assumption that we can reduce pollution by a factor of four. Why not 40 or 400? At this critical juncture, the anti-growth school musters no evidence at all. Yet, could not one argue plausibly that the technology of pollution-

suppression may increase its effectiveness exponentially, along with growth?

In the end, we are left, to be sure, with the long-run problems of carbon dioxide and heat. The former may be avoided by a shift of technologies away from combustion toward nuclear fission or fusion; the latter remains a brooding presence. It is only fair to add, however, that the presence is uncertain. The measurements of changes in the temperature of the earth's ambient are imprecise; we do not even possess very accurate knowledge of the relative effects of man's heat pollution compared with nature's—there are, after all, volcanoes, geothermal springs and currents, the steady heat input of solar energy. Thus, while there is every reason to be cautious, panic is hardly indicated. "The principal defect of the industrial way of life with its ethos of expansion," begins "A Blueprint for Survival," "is that it is not sustainable." In the end, that charge, with its exponential emphasis, cannot be faulted. That end, however, is still probably far distant. The question, then, is what to do about it now.

IV

The authors of the "Blueprint" and "Limits" have a very clear idea of what to do about it now. We must engage in an all-out effort to bring about zero population and zero industrial growth as soon as possible. To that end, every technological means to reduce waste, expand resource availability through recycling, and to lower pollution must be vigorously pushed. But ultimately, the prime requirement is the attainment of a society in which both the size of population and of the capital stock are stable. In a word, the only solution for ecological equilibrium is the stationary, growthless state.

This is a very curious solution for two reasons. The first, to which the studies pay only fleeting heed, is that a "stationary" state—one in which industrial growth had ceased—would not necessarily be a society in ecological balance. This is because a society can be "stationary" and can still be polluting the environment. Indeed, under the assumptions of the M.I.T. model, a stationary state will still asphyxiate itself, although it will take somewhat longer to do it.

Second, a stationary state, as we have seen, would impose fearful costs on the populations of the underdeveloped world and severe institutional strains within the industrialized world. Sup-

pose, however, that it were possible to go on growing—producing more grain, more consumer goods—*without adding to pollution,* by the discovery of new and better seeds, or cleaner production processes. Would there then be any reason to deny more food and more consumer goods to the poor, or even to the rich? I can think of none, and I suspect that the members of the anti-growth school cannot either.

A very important conclusion follows. As the M.I.T. models themselves show, it is not "growth" that is the mortal enemy, but pollution. The program of the ecologically minded scientist, therefore, should not be aimed against growth, but only against pollution-generating growth. Any technological change that will increase output without further damaging the air or water or soil, any technological change that will enable us to increase output by shifting from a less to a more abundant resource (again, without an increase in pollution), represents perfectly safe growth, and should be welcomed with open arms.

This emphasis on finding "cures" for pollution, resource exhaustion and population growth clearly puts technology in the key position. To this, the M.I.T. scientists reply that too much reliance on technology diverts us from taking "effective action" on the problem of growth. Does it? Let us assume that the anti-growth scientists are correct, and that they convince their colleagues around the world that collapse will be inevitable within a generation or two unless fully corrective measures are begun today.

What sorts of measures would these be? In the underdeveloped world, we would certainly require the imposition of compulsory birth control aimed at a negative net reproduction rate (say only one child—not one *female* child—per family); in the advanced countries, stringent measures to bring immediate zero population growth. In the underdeveloped world, we would have to stop the green revolution with its agricultural increases bought only at the expense of vast, pollution-generating fertilizer inputs; in the developed world, we would necessarily anticipate decreases in food production as a result of a ban on chemical fertilizers. Further industrialization might perhaps be permitted in the neediest countries—a few steel mills in Asia and Africa; an absolute halt to capital formation would be necessary in the West.

I could extend the list of particulars, but there is little point

in doing so. For it is clear that the imposition of such a program is far beyond our existing political and social capabilities. What Asian, African or South American leader, confronted with all the scientific evidence in the world, would endorse such a program for his people now? What Western statesman would advocate a program of immediate asceticism to avert a disaster that is still at least a century away?

What is at stake here is more than the obvious resistance that such measures would encounter from existing political and economic institutions. It is also a matter of our personal willingness to undergo present sacrifice for the well-being of our unborn progeny. I have wondered, for example, how many of the 100-odd signers of the "Blueprint" and the "Limits" have sold their automobiles or never take a taxi? I wonder how many have dispensed with all unnecessary gadgets in their homes, use both sides of the page when they type a manuscript, flush their toilets but once a day, and generally conduct themselves with the Spartan restraint integral to a program of economic limitations such as they urge?

In a differently constituted society, such an identification with future generations might be possible. It is not easy to find in our own. Of course I know that a beginning has been made. Some toxic products have been banned. Anti-pollution laws have been written. A concern for ecology has become part of the standard political rhetoric. But measured against the scale of action demanded by the anti-growth scientists, what has been done is pitifully inadequate. Anti-pollution measures have been contested and evaded by powerful economic interests. The determination of family size has been declared by our President to be a "personal matter." The most casual inspection of cityscape or landscape testifies to the lack of concern for our own generation, much less for coming generations.

The problem evaded by the anti-growth school, in other words, is how to mobilize the social will—how to induce us to apply *existing* technologies against the resistance of entrenched interests and ordinary people alike. If we are to mount a response on the scale they propose, I suspect there is only one way—by the ghastly appearance of the initial stages of ecological disaster itself. A temperature inversion that takes the lives of a few thousand people in New York or Tokyo may lead to banning cars and smoke from those cities; a horrifying rise in infant mortality

traceable to nitrate-based fertilizers may bring effective bans on chemical additives to the soil. Short of such terrible stimuli, I do not believe that the pace of industrial growth will be significantly slowed in the cause of environmental safety or that the overloading of the environment will be significantly diminished. Thus if, in the end, I pin my faith on "technology"—meaning the search for resource-extending and for pollution-suppressing techniques, even if they remain for a long while unused—it is because I cannot think of anything today that is more likely to be useful in the solution of the problem that one day mankind will have to solve.

V

That brings us finally to the fundamental problem of containing within a finite system an ever-mounting volume of contaminants. Here, as I have said, the scientists are right. However "alarmist" the data on which their models are based, however naïve their call for social change on a scale that is beyond reach and by means they do not make explicit, one cannot fault their assertion that the exponential curves of growth, human and industrial, will sooner or later overtake the finite capabilities of the biosphere, bringing dreadful declines in population and in the quality of life. I have suggested that the period of grace before that time of catastrophe and collapse may be considerably longer than they project, but it is not an indefinite period. Sooner or later the problem must be faced.

But how is it to be faced? Let me try to answer the problem by stressing an aspect of it which we have hitherto ignored—the extent of the institutional changes needed to attain a condition of ecological equilibrium. Central among these changes will assuredly be the extension of public control far beyond anything yet experienced in the West, Socialist *or* capitalist. To bring environmental stability, the authority of government must necessarily be expanded to include family size, consumption habits, and of course the volume and composition of industrial and agricultural output. In a word, the social price of ecological control is a vast increase in the scope and penetration of regulatory authority, designed to enforce the necessary zero-growth behavior at the micro level on which our collective safety will depend at the macro level.

It is here that my scenario departs most strikingly from that

of the authors of the "Limits" and the "Blueprint" and the anti-growth community in general. More sanguine than they about the technological possibilities of continuing industrial growth for a considerable period, I am far more pessimistic about the ease with which such a social transition can be made.[4] In the West, for example, surely the eventual necessity for a stabilized flow of output (quite aside from the other regulatory interventions that may be needed) spells the end of the mindlessly self-aggrandizing corporation as we now know it. Whether capitalism can adapt to the tensions of such a static state, in which growth no longer tempers the struggle over the division of the social product, is a moot question. If something called "capitalism" does survive, it will surely be cast in a very different mold than it is today.

Nor is the prospect an easy one for the industrial Socialist nations. Ministries as well as corporations find the ethos of growth both exhilarating and socially useful, and will find the constraints of a growthless state much more cramping than those of an expanding one. Perhaps more fundamental, socialism has always assumed a condition of "abundance" as the precondition for the inauguration of a "true" Communist society. Given the constraints of ecological limits that cannot be safely breached, that ideological premise must be abandoned; and the institutions and incentives of true communism re-thought.

More sobering yet— for who cares, in the perspective of ultimate environmental safety, if the institutions of present-day capitalism or socialism disappear?—is whether global requirements of pollution control and resource conservation can be imposed on—or will be shattered by—the ferociously guarded boundaries of "national interest." Indeed, we might well ask whether the approach toward the ecological disaster point will encourage the more equitable international distribution of the means of life, or will only serve to fortify the resolve of favored nations to preserve their own good fortune against the rest?

Thus the ecological problem is indeed fundamental—but in another way than that which the anti-growth scientists stress. Essentially, their dilemma of exponential growth and finite envi-

[4] The authors of the "Blueprint" do indeed describe a kind of balanced social system in which ecological safety is maintained by carefully planned small rural communities. Like all Utopias, it is a joy to contemplate. Alas, like all Utopias it contains not a word as to how we are to go from where we are to where we are supposed to be.

ronmental space involves problems of technology that will be solved—or will not be solved—over a fairly long run. But much more immediate, there is another problem in the social changes that will have to be begun in our generation and carried further in the next generations to come. The "fundamental" problem is therefore a social as well as a technical one; and whereas I have indicated some reason for optimism with regard to our technical capabilities for adaptation, I do not find it so easy to be sanguine with respect to our near-term ability to bring about the needed social and institutional changes.

But that very fact may help us answer the question with which we began and with which we now end: how is the environmental challenge to be faced? For clearly something is required in addition to that "sense of detachment and balanced appraisal" of which I spoke before. This additional element is the cultivation and gradual dissemination of a changed attitude to the environment—indeed, to life itself: an attitude based on a wholly new awareness of the fragility of our planet as a life-supporting vehicle.

As I have stressed, it would be foolish to expect such a change in attitude to manifest itself quickly in the face of the needs, the desires, and the institutional inertias of our time. None the less a beginning can be made—indeed, is being made by the very arguments we have been considering in this piece. In becoming aware of the hitherto unsuspected existence of a crucial environmental challenge, we feel within ourselves the first stirrings of an unaccustomed view of the human future, and of our responsibility for assuring that there will be a human future. Our generation is unlikely to solve the technical problems that will guarantee the indefinite viability of the planet, and will surely not solve the social challenges that are indissolubly associated with mankind's survival. But in the startled recognition that an ultimate ecological problem exists, it can set the stage for more decisive action by generations to follow.

'THE LIMITS TO GROWTH' IN PERSPECTIVE

A paper submitted at the request of
The Economic Committee of the Parliamentary Assembly of
The Council of Europe

by Aurelio Peccei
and
Manfred Siebker

December 1972

'The Limits to Growth' in Perspective

There are no internal affairs left on our crowded Earth. And mankind's sole salvation lies in everyone making everything his business.

Alexander Solzhenitsyn

We are travelling together, passengers on a tiny space vessel, tributaries of vulnerable resources like water, air and land, all conjointly responsible to guarantee our safety and peace. We cannot escape from annihilation other than by the care, the labor and, I should say, the love which we dedicate to this fragile vessel. We will not be able to succeed as long as one half of the crew lives in wealth and the other in misery, as one half exuberates in self-confidence, whereas the other lives in despair...

Adlai E. Stevenson

The two worlds of man - the biosphere of his inheritance, the technosphere of his creation - are out of balance, indeed potentially in deep conflict. And man is in the middle. This is the hinge of history at which we stand, the door of the future opening on to a crisis more sudden, more global, more inescapable, and more bewildering than any ever encountered by the human species and one which willtake decisive shape within the life span of children who are already born.

Barbara Ward and René Dubos

Our present society is based materially on an enormously successful technology and spiritually on practically nothing.

Growth had become synonymous with hope, and men cannot live without hope... They unconsciously repeated St Augustine's prayer :'Lord, make me good, but not yet!' Let exponential growth continue in my time !

Dennis Gabor

The greatest crime is not described in criminological books: it is geocide, the destruction of life, of the biomass of the Earth.

Henri Ellenberger

The cult of sovereignty has become mankind's major religion. Its god demands human sacrifice.

Arnold J. Toynbee

INTRODUCTION

The present paper has been written at the request of the Economic Committee of the Parliamentary Assembly of the Council of Europe which is preparing a report on 'the limits to growth controversy' and wants a document arguing the case that such limits do exist.

The origin of the controversy the Council of Europe intends to explore is a 200-page book entitled The Limits to Growth, by Donella H. Meadows, Dennis L. Meadows, Jørgen Randers and William W. Behrens III (Universe Books, New York, 1972), brought out in English last March--and in many other languages since--at the conclusion of a research project on world dynamics commissioned by The Club of Rome to be performed by MIT.

We feel that the best way to form a fair judgment on an issue, a thesis or a piece of work is to place it in its proper perspective. This we will do in this case. In doing so, we will take the viewpoint of The Club of Rome--which by the way cannot be identified with the MIT project or any other project it may sponsor and support. This broad approach is at any event required when the purpose is not just reviewing a book, but interpreting an advanced piece of research and its yields, and correlating them to the general body of knowledge. In this instance, this procedure is the more necessary because the research carried out at MIT between July 1970 and the end of 1971 was not intended to be a one-shot operation, a self-contained project that can be examined and assessed focusing only on this book. Whatever the merits or demerits of the first study, it must be viewed as part of a

larger project The Club of Rome has undertaken to develop in the course of a few years on The Predicament of Mankind. Its overall objective is to acquire a deeper understanding of how to face the multiple problems which harass human society at this turn of history--and which are due to growth factors only in part.

Even if the MIT work were considered in isolation--an exercise that would however leave some major aspects of the growth issue itself untouched--it could not be judged by concentrating on this book only, because its theoretical and methodological foundations and their first pragmatic application to world problems are to be found in another book, Jay W. Forrester's World Dynamics (Wright-Allen Press, Cambridge, Mass., 1971). In it Professor Forrester, the originator of the 'systems dynamics' techniques applied earlier to industrial, urban and social 'microsystems', explains how he adapted them, at the request of The Club of Rome, to embrace the global 'macrosystem'.

The picture would be likewise grossly incomplete if the Technical Report compiled by the MIT Work Team were to be neglected. We feel sure that many of the clarifications requested and a great deal of the criticism formulated after reading the limits to growth book will find an adequate response in this Technical Report of upwards of 900 pages. Earlier incomplete editions of it have been circulated. A complete text in mimeograph form has been made available recently by its Authors to all those who are interested in analyzing in detail the characteristics of the model, the data used and their sources, the interrelationships adopted, the computer runs made, or other technical aspects.

Furthermore, a number of ad hoc studies were carried out by the MIT Work Team on specific relevant topics in parallel with the major project. Annex A contains a list of these studies which may be obtained from the Work Team, while a more complete list is included in the book as an Appendix. We would reiterate that they should certainly be taken into account.

We do not feel competent to answer the questions that may remain unresolved even after due consideration is given to all these other documents, and believe that in this complex matter many issues are likely to remain without response anyway, or are points on which opinions will continue to be divergent or contrasting. We would however suggest that, with a view to reducing this area of uncertainty, the Council of Europe at some future date invite Professors Forrester and Meadows to discuss it with some of the people who disagree with them.

For our part, we are pleased about the lively discussion under way on the growth issue generally, and consider the highly emotional reaction to the 'limits' report the best indication that it has touched a nerve centre. At the same time, it is very important to our mind that the debate on this key issue should not descend into polemics and that it should be serious, thorough and in-depth--which unfortunately is not the case with many of the commentaries we have so far seen. Needless to say, finally, the interest shown in it by top political and highly representative bodies, and foremost among them the Council of Europe, is most welcome.

We are deeply indebted to various members of The Club of Rome, and particularly to Dr. Alexander King and the other members of its Executive

Committee whose ideas have been used in this paper. And we share their overall evaluation of the 'limits' report given in their <u>Commentary</u> included in the book:

"How do we, the sponsors of this project, evaluate the report? We cannot speak definitively for all our colleagues in The Club of Rome, for there are differences of interest, emphasis, and judgment among them. But, despite the preliminary nature of the report, the limits of some of its data, and the inherent complexity of the world system it attempts to describe, we are convinced of the importance of its main conclusions. We believe that it contains a message of much deeper significance than a mere comparison of dimensions, a message relevant to all aspects of the present human predicament."

However, this paper represents the views of its authors only, as individuals, and does not engage any other person or any group or organization.

1. The Changed Human Condition

1.1 Man's Ascent and Predicament

For millennia man has struggled upwards from mere subsistence, and throughout this period technical assets, however crude and unsystematic, have helped him to survive in hostile environments. Fire, the wheel, the plough, rudimentary metallurgical skills--these and other findings of great consequences led to a settled agriculture, the establishment of cities and the emergence of a whole series of craft industries. It was not until a great spiritual crisis occurred, however, that one part of mankind, Europe, ceased to be absorbed by the marvels of transcendentalized hierarchies and became fascinated instead by the laws of nature.

The wish to know soon enough became amalgamated with a now unhibited drive to implement the possible. This formidable mixture, which we call technology (so very un-Greek despite its name), was the essence of the industrial revolution, a critical point in man's development. It led to the explosion of activity, ugliness and wealth which became the threshold of the world we now know in the so-called developed countries, reaching its extreme in the United States. Natural science--finally recognized in the esteem of society--paved the way to a whole range of industries, mechanical, chemical and electrical, whose products are commonplace today and form the basis of the present materialist society of consumption and waste which prevails in the 'Westernized' part of the Earth.

At the same time the majority of mankind, living in the remaining

regions, although involved in this whirlwind of change, has only marginally benefited, but mostly suffered, from the dominance of technocratic nations--whose very gifts have often enough turned out to be poisoned.

In our time, advances in scientific research have been spectacular. The immense expenditures allocated to it in all industrialized countries provide a rich and expanding repository of knowledge, from which still further extensive new technological development is certainly emerging, with enormous but dimly perceived consequences for the future of society. We must recognize the outstanding success of science and technology in producing an upsurge of prosperity and economic growth to a level unprecedented on our planet; it has augmented and enriched our food supplies, lengthened our lives, brought health to millions, and provided them with leisure. To past generations, our era seen from this angle could appear as a golden age.

But science and technology, with all their advantages, have also been the main contributors to the complexity of the modern situation, to the extraordinary growth in population we are now experiencing, to pollution and the other unpleasant side effects of industrialization. We have no wish indeed to return to the situation of a few centuries ago when population growth was checked by starvation and disease; but we have not yet learned to control the present. And, lacking a clear view of our desired future, we do not know in precisely what direction to guide the enormous force which scientific and technological progress represents--a force which has the potential of progress or of destruction.

At this point, then, of near attainment in man's struggle upwards from poverty, disease and the enslavement of work, disillusion and doubt have crept in. We begin to perceive that in our technological society each advance makes man more impotent as well as stronger, each new power gained over Nature appears to be a power over man as well. Science and technology have brought us the threat of thermo-nuclear incineration as well as health and prosperity, the nightmare of ruthless manipulation of human genetic material as well as hope for overcoming cancer. Population increase and the drift to the cities have led to new types of poverty and imprisonment in a squalid urbanism, often culturally sterile, noisy and degrading. Electricity and motive power have lessened the burden of physical work but have leaked away satisfaction in such work. The automobile has provided freedom of movement but also led to fetishism for machines as well as cluttering and contamination of the cities. The unwanted aftermath of technology (or rather technolatry) is all too obvious and constitutes a threat, which could become irreversible, to our natural environment; individuals are increasingly alienated from society, and reject authority; crime and delinquency are on the increase; faith is on the decline, not only in religion, which has sustained man for centuries, but also in the political process and the efficacy of social reform. And all these difficulties seem to be growing with affluence.

Therefore, although emphasis is still on the desirability of increasing production and consumtion, in the most prosperous nations there is a rising feeling that quality is draining from life--and the foundation of the whole system is being questioned. At the same time, the situation in the less developed regions of the world is still more

preoccupying. Here the contrasts are even sharper, between the expectations raised by the magic of modern technology and the small share (if any) these populations can glean of a progress which elsewhere seems so glittering. Thus, in the wake of scientific and technological development, intolerable psychological, political, social and economic gaps have appeared, which oppose the 'haves' and the 'have-nots' of the world. Further aggravation of this state of affairs would make political explosions inevitable.

What is in fact wrong is that man has been so intoxicated by his newly acquired capacities that he grossly misuses and abuses them. Lured by the mirage of unending progress and growth, he has forfeited spiritual, ethical and generally non-material values, busily concentrating his best energies on creating a man-made world for his material comfort.

It is remarkable that the strangely intractable and elusive problems with which men everywhere are confronted--from the crisis of institutions to bureaucratization, from uncontrollable urban spread to alienation of youth, from increasing rejection of the value systems of our society to inflation--have three characteristics in common, in spite of their seeming diversity. Firstly, they have worldwide dimensions or impact, and appear at certain levels of development in all countries irrespective of the social and political systems in force. Secondly, they are complex and multivariant with technical, social, economic and political elements. Finally, they interact strongly among themselves in a manner we do not yet fully understand.

It is this intertwined clustei of problems which The Club of Rome

terms the Problematique. The interrelations are so basic and have become so critical that it is no longer possible to isolate any single major issue from the tangle of the problematique and deal with it separately. To attempt this only increases the difficulties in other and often unexpected parts of the mass. For the same reasons, no nation, not even the biggest, can hope to solve its own problems if those threatening the global system remain unresolved. Our customary methods of analysis, our approaches, policies and governmental structures, all fail when faced with such complex situations. We do not even know whether and what unwanted, mediate or indirect, consequences may be provoked by our alleged 'solutions'.

This then is The Predicament of Mankind: we can perceive the individual symptoms of the profound malaise of society, yet we are unable to understand the significance and interrelationship of its myriad components, or diagnose its basic causes, and hence are at a loss to devise appropriate responses.

1.2 Man's New Role

Confronted with this baffling and threatening problematique, society is hard put to to adapt to it, and shows symptoms of a collective syndrome manifesting itself in neurotic if not psychotic behaviour, ranging from impulses of reckless consumption to drug addiction, from unreasonable aggression and violence to the fatalistic depressiveness of those who see inevitable doom. Only recently it is dawning on people here and there that human society is facing a serious crisis in its evolution which may even affect the destiny of

the species, and this generates a newly-won human solidarity which--while still dispersed--tends to overarch our traditional, national, ideological or racial divisions, recognizing the basic oneness of mankind. The tackling of the predicament however needs a powerful rational superstructure.

Man's condition has fundamentally changed in his world; and now he is called to fulfil a new, cybernetic role in it. On the one hand, he has reached such a dominant position in the ecosystem that he is compelled to take upon himself regulative and normative functions heretofore left to the inscrutable designs of Nature or Providence--which requires of him exceptional new qualities of 'ecological wisdom', both words being employed here in their broadest meaning. On the other hand, he has created such an intricate and integrated human system that its regulation and functioning cannot any longer be trusted to automatic mechanisms--man must manage himself his system, developing hitherto unimaginable qualities of 'socio-political wisdom'. Such novel, all-embracing wisdom is far more important than any new technological breakthroughs; for man has made of himself the major agent of change in the world, and what will occur in it in the decades and centuries to come depends on how wisely he uses his immense power. "His role, whether he wants it or not"--says Julian Huxley--"is to be the leader of the evolutionary process on Earth, and his job is to guide and direct it in the general direction of improvement". In a word: man has to realize his responsibility of the truly 'cybernetes', the pilot and helmsman, governor of 'Spaceship Earth'--which at present is drifting along dangerously.

This is the challenge to our generation. The longer we hesitate in recognizing it, the more reduced the options become for us and the next generations. Probably, the first effort has to be of a philosophical and intellectual character. With respect to our environments, we must prepare for self-restraint and self-discipline, and direct our knowledge and technology rather towards protecting Nature and the other forms of life than over-exploiting them, as well as managing the use and conservation of the world's patrimony of soil, water, air and geological deposits. In the social, political and economic order, we must see the collective good take precedence, and individual initiative and profit, even freedom, become subordinate; and substitute for the fatal ideal of national sovereignty and closed-circle interests that of a hierarchy of inter-dependent human groupings or systems, where the requirements of the higher levels come first, and at the top are the requirements of the world system. And, more generally, we must accept the rule that expansion or benefit in some area or field usually requires a counterbalancing reduction or sacrifice elsewhere, now or in the future, and that we had better plan these trade-offs, even when they are painful, than leave them to chance.

Altogether new rational approaches have to be developed if we are to assume the cybernetic role necessary to guide our fortunes in the decades and centuries to come. This forward thinking and planning has to be more than just the sum of singular projections into the future in a number of important fields--such as the economy, security, education, or science policy. To meet the world's reality and problematique on their own terms, our rationale has to match their dimensions with an approach that must be, at the same time:

- Systemic, in order to envision and analyse not individual issues, but the clusters of systems into which human activities and expectations are channelled, their interrelationships with the natural environment, and the maze of problems which derive from their multiple cross impacts.

- Global, or system-wide. Since many key issues have become so large as to exceed national or regional bounds, this means worldwide. Our 'spatial horizon' cannot be narrower than the consequences of our actions.

- Diachronic (the parametric extension of the systemic dimension into time). Our 'temporal horizon' should embrace all moments during the whole period of the possible consequences of our actions.

- And finally, normative, or goal-oriented. Setting long-term global goals, both feasible and acceptable to the entire mankind is the most difficult challenge, but it is the most vital as well at this point in man's evolution.

Without an urgent, intensive acculturation to update and upgrade our value system, this Copernican revolution of hearts and of minds cannot occur. We will be unable to fulfill our inescapable role, and remain prisoners of our prejudices, taboos, and motivations of other ages, our cultural bases, our thinking and behaviour utterly inconsistent with our new condition and power. This vicious circle can but end in disaster--and must be broken before it is too late.

. The Club of Rome: Purpose and Action

2.1 Origin and Objectives

One has to bear in mind the preceding evocation of man's actual predicament and the vision of his new role to understand the climate that produced The Club of Rome--and consequently the study on the limits to growth. The starting point was some conversations held in 1967 in Paris, which led to the decision to call together in April of the following year at the 'Accademia dei Lincei' in Rome a group of Western European intellectuals and scientists to discuss the world problematique. The meeting was made possible by financial support from the Agnelli Foundation. At the end of the meeting, a few of the participants decided to continue the discussions in a widened circle and named their group The Club of Rome after the place of its initiation.

At present, the Club comprises some eighty members, including scientists, humanists, economists, educators, civil servants and industrialists. Although its total membership is limited to one hundred, it is being selected to include representatives of a wide variety of cultures and value systems; and although none of them is involved in current political decisions, nor has the Club as a whole any ideological, political or national commitments, together they have access to decision makers and possess great stores of information and knowledge to draw upon. These individuals of widely different experience and origin have one conviction in common: that the problems now facing mankind are of such complexity and interrelationship that traditional policies and institutions are no longer able to cope with them.

The Club's objectives, including both research and action, are grouped in a wide-ranging project called, after the situation it wants to meet, The Predicament of Mankind. It is directed at:

= Acquiring and diffusing a real in-depth understanding of the critical state of human affairs and the narrowing and uncertain prospects for the future, and thus creating a climate for action with the more responsive world public opinion and decision makers;

= Recognizing and proposing new policy guidelines and organizational patterns to manage the human lot more intelligently in the future.

Due to the Club's nature and dimensions, its action can be only catalytical. The 'limits' research is its first major manifestation.

2.2 Need for Deeper Understanding and New Communications Tools

After its formation in 1968, The Club of Rome devoted the first two years mainly to establishing contacts with key scientific, industrial and political circles in many parts of the world--from Moscow to Washington, from Tokyo to Ottawa and Rio, and in Europe. Its opinion that the problems of modern society were growing and becoming more intractable, with the risk that the situation in many societies might get out of hand, was widely shared; but generally these high-placed personalities seemed to consider themselves powerless or were unwilling to do anything about it. Many others, engrossed in reaping short-term benefits, had a *carpe diem* attitude, or just hoped that something would sometime turn up and set everything right again. As a matter of fact, the repeated and pressing exhortations of U Thant,

of the World Council of Churches, the Pope and other moral and spiritual leaders, and even the protests of youth had so far succeeded in but barely denting the Olympian official conviction, or wishful thought, that mankind is on a basically satisfactory course--which just needs an odd correction, here and there.

One clear demonstration of the ineffectiveness of this hortatory method is the pathetic and urgent 'Menton Message' addressed by 2200 environmental scientists from 23 countries to warn their three and a half billion neighbours on planet Earth of the unprecedented common dangers facing mankind. This cry of alarm went practically unheeded. Another example of meagre yields is provided by the United Nations world conferences on matters of great import. Such are the UNCTAD conferences, the third of which was held this year in Santiago, and the Stockholm Conference on Man and His Environment which followed on its heels. Nor are expectations high, either, for the 1974 Conference on Population, which may well become another grand arena for mass rhetoric and power politics, leaving this cardinal issue more obscure and controversial than before.

Clearly, the inertia keeping society on the present course is a formidable force. Other, more powerful and comprehensible tools of communication and conviction than those now used were necessary if world public opinion and policy makers were to be moved --tools which would reflect the inherent complexity of the message The Club of Rome wants to put through, and yet have a strong, lasting impact on people's hearts and minds.

Professor Jay W. Forrester of MIT, participating in the Bern meeting

of the Club in 1970, thought that he could forge one such tool by upgrading his 'systems dynamics' techniques already successfully utilized to simulate and analyze large and complex social problems in the urban, regional and corporate spheres, and make them applicable to nothing less than the entire world system. His proposal was accepted, the Volkswagen Foundation generously made financial provision for the project, and a team of scientists under the leadership of Professor Dennis L. Meadows was constituted.

It is the report of this team, published in March 1972 under the title of The Limits to Growth and the debate it has triggered off, and which reverberates in all parts of the world, that we are trying to put into perspective in this paper.

3. The Research Project at MIT: A First Step

3.1 Its Character and Inherent Limitations

As already mentioned, this first research, undertaken at MIT, is a study of world dynamics, namely the trends and the cross impact of some critical and quantifiable factors which characterize modern society: population growth, food production, industrialization, natural resources depletion, and pollution. It essentially explores the effects of the interaction of the growth modes of these variables, which mutually influence and often reinforce one another. And, even if what it can do is but a first assessment of the combined results of these growth trends, the MIT study conveys in effect, and for the first time, a panoramic view of the world's workings--which could

never have been obtained by making a separate analysis of each of these interlinked elements. It is worth noting in this regard that, as the demonstrative effect of the project was deemed necessary at the earliest date possible, only the factual information, forecasts and computer techniques available were used, without embarking on research in these areas.

When The Club of Rome asked MIT to make this analysis of world dynamics, the aim pursued was essentially to show in a comprehensive and comprehensible way what futures might stem from the present according to current behavioural modes, inherent time constants, perception of problems and 'classical' remedies.

The project was thus expected to be, and substantially is, a description of the present dynamic situation and the outcomes which are inherent in and consequential to it--if mankind's main course is not substantially changed. In other words, the MIT study was not intended to indulge in predictions, to be itself a piece of futurology, an attempt to draw likely scenarios for the world or any part of it at any time in the future.

At the same time, The Club of Rome was aware that the research would probably conclude with a very serious warning that unless a great change of direction does occur, mankind is heading towards a series of grave crises--possibly of unprecedented dimensions, as is everything today with respect to the past, and will be even more so in the future with respect to today. But it was clear from its inception that the MIT projections could and should not try to anticipate how, where and when these crises would happen, or what their sequence and aftermath could be.

Since the MIT research is then explorative, not even predictive, even less can it be prescriptive. The whole of the project is an invitation to think where the present world dynamics may lead us, and it is a means to arouse our awareness, a cry of alarm maybe, but certainly not an instrument for planning or decision-making proper. This nature and scope of the project could not eliminate a certain degree of subjectivity on the part of the Work Team--a subjectivity which, we feel, is no greater than that which characterizes the mental models on which human decisions are currently based. It is true that, confronted as they were day after day with the evidence emerging from the study that continuous, indefinite growth would lead to disaster within a few generations in spite of all imaginable orthodox measures, the MIT Work Team did express opinions as to the necessity to guide the human system away from the present growth stance to a 'situation of equilibrium'. But it would be naive to infer that these preliminary philosophical and general considerations--which the signatories on the whole share--are in themselves normative, namely that they contain precise norms for action.

In spite of the limited scope of the MIT project, many of its supporters or adversaries have tried to read into it much more than it actually is. Let us then repeat that this is a pioneering exploration along a new road in search of vantage points from where a reasonably comprehensive overview of man and his world can be obtained; and that to gain a first foothold on it, it was expressly decided not to invest time and energy to improve the existing modelling techniques or to correct the uneven and often biased body of data available. To position this pilot project correctly in perspective, one can liken it to

the early attempts of those pioneers who at the beginning of this century demonstrated that man could fly. Now this project has tried to demonstrate that man can have a universal view of self and Earth--and according to our judgment it has succeeded. The age of aviation started some sixty years ago. That of global thinking in operative terms is probably starting now.

In the general strategy to approach effectively the world problematique, the MIT undertaking can be considered, functionally, as a commando operation. It was aimed at breaking a stalemate situation and transforming it into one of dynamic debate as a prelude to action. The Club of Rome thought that one could not wait four or five years to have the study refined in every detail or supported from an important body of academic consensus before presenting its rough conclusions to world public opinion. The incredibly wide diffusion of the report--in some twenty languages--and even the bitterness and acrimony of the current debate show that this has been a good short cut. We will examine later on the importance of this initial impact, and how it can be exploited.

3.2 Summary of Basic Assumptions and General Conclusions

The objective of this paper is not to restate the findings of the 'limits' report. For self-explanatory reasons, however, and in order to facilitate the reader in judging seriously the degree to which the antitheses and counter-arguments--reviewed in the next chapter and in Annex B--are relevant or not, a glimpse of the main assumptions adopted in the model and of the general conclusions is given.

As a preliminary remark one should note that essential elements of a physical character only (e. g. food, raw materials, energy, ecology) and social factors (e. g. peace, social stability, education, research, employment) influencing them were considered. The basic and more elusive anthropological aspects of the human predicament were not taken into account, as they call for much more systematic treatment and special studies, which no doubt are going to expand and deepen, and probably also modify, the vistas offered by this first research.

In the various model runs, assumptions of different degrees of severeness were employed. However, since it is frequently said that over-pessimistic hypotheses only were chosen, we want to dispel such misgivings by listing below the most optimistic assumptions used in the study, and then some of the model responses. Here are these assumptions:

Food

= Exploitation of all arable land is considered possible (regardless of soil erosion, city growth, etc.).

= Quadrupling of present productivity is assumed, each doubling in about 30 years.

= Sufficient fresh water is supposed available (though this is one of the biggest bottlenecks already now).

Resources

= Energy: unlimited (1)

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(1) Even if Alvin Weinberg's prospects of using nuclear reactors for all energy needs were feasible from the fuel supply standpoint, the pollution hazards would be frightening: imagine 24,000 reactors in operation, each six times the biggest size used today, with a replacement ratio of two per day supposing their average life to be 30 years! (UN Conference on the Peaceful Uses of Nuclear Energy, Geneva 1971).

= Non-renewable mineral resources (aggregated): five times the present estimated reserves (corresponding to 500 years at 1970 consumption).

= Use of such resources: input reduced by a factor of 4 per unit of industrial output (from 1975) by reclamation and recycling.

Pollution

= Reduction to less than one-fourth of the present generation rate per unit of economic output (all sources aggregated, including agricultural pollution by fertilizers, pesticides, etc.). (1)

Birth Control

= Perfect in the sense that it prevents the birth of unwanted children (from 1975). (2)

Technology

= Assumptions as to its relative development are not explicitly stated but are implicit. In terms of effect (productivity, disentropic efficiency, etc.) a technological development rate much higher than today's is presupposed at least for a considerable period of time: e.g. permitting the use of fuel and mineral supply of decreasing quality, recycling of non-renewable resources and creation of means for 'perfect' birth control.

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(1) The long-term destruction of the biomass by factors other than pollution proper (urbanization, overfishing, single-cropping, etc.) is not considered, although perhaps more disastrous.

(2) Even if the medico-technical problem were solved in a practicable way, the main hidden question, cultural and motivational, would remain. There is considerable evidence that it is not so much ignorance and lack of access to birth control devices that are responsible for the high birth rate of the poor, as the urge to generate children (for many reasons, and perhaps mostly the absence of alternative modes of personal gratification and affirmation).

By and large, if this set of assumptions is unrealistic, it is because of their over-optimisms. Now, using them, the model shows that serious non-reversible crises (sometimes also called collapses) will nevertheless occur well within the next 100 years, the nature of these crises (food, pollution, resources) depending on the particular set of parameters chosen for the respective model run.

In the model's logic, the only way to avoid or attenuate this disaster-bound behaviour is the concomitance of limitations both in population <u>and</u> in capital growth--provided they are adopted in time. Two illustrative examples are given, both presuming strong remedial action embodied in the following world policies:

= The population has access to 100 percent effective birth control.

= The average desired family size is two children.

= The average industrial output per capita remains unchanged (excess industrial capability being employed for producing consumption goods rather than increasing the industrial capital investment rate above the depreciation rate).

Assuming these policies can be made effective in 1975, the outcome is a situation that seems generally acceptable:

= Population increases for another 70 years up to about 6.5 billion people.

= First a rapid, then a slower increase in food production per capita occurs, up to 150% of the present value by the year 2100.

= Industrial output per capita increases in the same period by one-third (in absolute terms by 130%).

= Depletion of resources is about 40% by 2100.

On the hypothesis instead that these policies are not implemented until the year 2000, the situation is bound to deteriorate possibly beyond repair. In fact:

= Population increases to about 8. 5 billion in 2040.

= Food production per capita doubles within 50 or 60 years, but decreases markedly from 2050 onwards down to little more than the present value.

= Industrial output per capita increases more rapidly, up to 240% in 2040, but precipitates afterwards to three-fourths of the present value.

= Depletion of resources reaches almost 80% by 2100.

In this second case, an equilibrium state is no longer attainable in the world, and food and resource shortages would be inevitable and crippling. Presented in today's terms, if the shortage first reached were that of food production, the population of the non-industrialized countries would suffer most and be drastically reduced; while if exhaustion of non-renewable resources occurred first, the industrial countries would be most affected. Whatever fraction of the human population remained at the end of the process, it would have very little left with which to build a new society in any form we can now envisage.

Before reviewing the criticisms, we want to underline again that these are not predictions or forecasts, but indications of outcomes reasonably to be expected if the present world dynamics are not changed by the only agent which can do it--we ourselves. This is expressed in the general conclusions of the report as follows:

"1. If the present growth trends in world population, industrialization, pollution, food production, and resource depletion continue unchanged, the limits to growth on this planet will be reached sometime within the next hundred years. The most probable result will be a fairly sudden and uncontrollable decline in both population and industrial capacity.

2. It is possible to alter these growth trends and to establish a condition of ecological and economic stability that is sustainable far into the future. The state of global equilibrium could be designed so that the basic material needs of each person on Earth are satisfied and each person has an equal opportunity to realize his individual potential.

3. If the world's people decide to strive for this second outcome rather than the first, the sooner they begin working to attain it, the greater will be their chances of success."

3.3 Review and Assessment of Criticisms

The wave of criticism raised by the study has many facets of varying nature. As usual, some of the objections are to the point, others off-centre, some referring to things actually said, others referring to imaginary theses falsely attributed. The confusion is often great--e.g. that between diachronic analysis and prophecy. (Incidentally: calling somebody Cassandra is rather double-edged: Cassandra proved to be right!)

The bulk of the criticism is based on one or more of the following ways of reasoning:

= The assumptions are wrong (that is: too pessimistic).

= The model is imperfect.

= The presumed remedial policies are unrealistic or the alternatives to present society are unacceptable.

= More important problems are not dealt with.

A short discussion of each of these categories is given below, while in Annex B some of them are examined in the form of point and counterpoint. We shall deal here mainly with the objective and constructive criticism--which The Club of Rome sincerely welcomes--rather than the emotional sort, although it is most instructive to see how in many cases they overlap.

As already indicated, a thorough analysis of the criticism can be made only by a confrontation between their proponents and the MIT Work Team.

3.3.1 Criticism of the Assumptions

In the field of demography and the interpretation of population phenomena opinions are generally divided. Recurrent criticisms are based on hope for a fast demographic transition in poor countries, or on under-estimation of the time lag between birth control and population stabilization, or neglect the age structure as a factor, or treat population growth in industrialized countries as a minor matter. These arguments do not hold against proven knowledge.

The attempts to prove that the assumptions on food availability

are too pessimistic are unconvincing as well. 'Green revolution' advocates, and even Nobel laureate Norman Borlaug, seem sceptical about the material feasibility of the future production quantities assumed by MIT, even disregarding social and ecological costs. Harvesting more food from the sea and having recourse to synthetic food may help to defer a crisis somewhat, but are to be ruled out as permanent solutions of the problem.

Non-renewable resources are a much more complex subject, on which some serious and constructive critical remarks have been made. In fact, some of the data used in the study have a rather low confidence level, while others seem too conservative in view of the possible use of low-grade though high-cost base materials or of new sources, such as seabed extraction. More research on resource availability is needed before definite statements can be made on the effective life of critical materials and their possible substitution. There is however good reason to believe that the basic overall conclusions of the study will not be fundamentally changed, also because the very nature of the predicament lies in the fact that its problems are too strongly entangled for success on any isolated item to change the total picture.

As to substitution, it involves other resources (an important consideration if substitution is generalized), or may be based on technically feasible but uneconomic extraction processes (e.g. seawater or rock extraction), or else may require enormous additional energy consumption or forbidding invest-

ments syphoning money away from other needs, and finally is likely to be another source of pollution. Along with recycling (assumed in the study to reduce resources demand by a factor of 4), which at any rate faces similar problems, it requires also a change in social behaviour, with legal and fiscal implications.

The optimal assumption of limitless energy is perhaps one of the weaker points of the study, especially in view of the probability of an energy crisis within the next twenty years owing to scarcity of petroleum and natural gas, while the phasing-in of fast breeder reactors and massive utilisation of thermal, in particular high-temperature reactors, is still terribly uncertain. The need to push ahead with R&D and planning or simply to know more in the field of high energy liquids from coal and lignite, the utilization of tar sands, or other energy sources is urgent since the provision of sufficient energy is quite a critical point in relation to the adoption of stop-gap or even basic technological solutions to increase the time to manoeuvre towards a more stable and secure society.

Another relatively weak point of the model assumptions (and of the respective model structure) concerns pollution; the aggregation is by all means extreme, and the hypotheses on death rate values as a function of pollution are rather arbitrary. The report though makes it clear that its consideration of the pollution aspects is fractional in that it concentrates exclusively on the accumulation of products which are non-biodegradable or decompose very slowly (e. g. DDT and mercury)--a point on which ecologists are

very alarmed, excessively so, it is to be hoped. This whole matter is again one for long-term research before one can speak conclusively one way or the other. Time only can prove the pessimists or optimists right.

Some critics of rather general argumentation, emphasize the success the city of London achieved in air pollution abatement--an atypical case of pollution very ably and decisively handled--forgetting at the same time that the situation in Los Angeles, Tokyo and Milan has by no means improved. The most worrying pollution anyway is not that of air but of water (lakes, rivers, ground-water and finally the ocean), climbing from there into the food chain. A final caveat: not dealt with in the study (although mentioned) but perhaps even more disastrous than pollution proper, is the increasing destruction and retrogradation of the Earth's biomass, the equilibrium of which is already severely compromised, as mentioned before, by the unabated, extraordinary expansion of the presence and activity of one single species--that of man.

Technology as the ultimate answer to all prayers is a leitmotiv to be found in the criticisms of the most diverse kinds. In many parts of this paper we decry the fervid and naive reliance on technology as a cure-all. A general statement is perhaps befitting at this point. We find it in an interesting document (*) which says that this kind of belief rests, if on anything rational, on the premise "that the steady technical progress of the past century or two can be sustained indefinitely into the future, and that science and technology are flexible with respect to goals, i. e. that they will be as effective in dealing with pollution or materials shortage

(*) 'Technical Change--Social Change?' by the Science Policy Research Unit at Sussex University in the Field of Forecasting, September 1972.

as they have been in developing communications technology or in raising productivity in oil refineries or making nuclear weapons. Now, technical progress has been won at steadily increasing cost and specifically the returns to R&D investment have been steadily diminishing for the past century. Economists are unanimously agreed that the rate of increase in R&D expenditure in the past 50 years has been far greater than that of the GNP or of any of the indicators of technical progress in the economy. Even if technological solutions to these problems can be found, national and international social systems may simply not be able to accommodate the necessary rate of change". One should add moreover that the net useful output of new industrial techniques will become relatively smaller and smaller as more and more effort and ingeniousness have to be devoted to remedying harmful side effects of primary techniques.

3.3.2 Criticism of the Model

The pilot nature of the model is not always acknowledged, nor is the fact that its high degree of aggregation justifies imperfections which may be overcome only in later model generations. The absence of adjustment mechanisms in the model is often noted instead with the observation that especially in the functioning of the economy these--and particularly price--play an essential role.

It is true: only a few adjustment mechanisms (like the birth rate as a function of per capita income) were introduced into the model. But, for one thing, in the real world social mechanisms do adjust insufficiently, and at any rate with too long time lags with respect to modern growth and change rates, e.g. in technology,

industrialization and urbanization; or they do correct just one part of the system, possibly disrupting other parts. In fact, no adjustment mechanism so far has prevented the formation of untenable situations in world nutrition, or city transport, or the cancerous growth of metropolitan areas filled with misery, or the extreme disparity of wealth among and within countries. However, we do recognize that price as a regulatory factor has not been given enough importance in the model, even if it is no longer a valid regulator in many fields, often being itself the resultant of many other factors perturbing the genuine demand/supply relationship.

3.3.3 Criticism of the Presumed Policies and their Outcome

In order to stabilize the MIT world model for the period until 2100 and possibly beyond, the simulation of several simultaneous remedial policies was necessary, concerning mainly birth control measures and limitation of the average industrial output per capita. Some critics rightly deduce that the implementation of such policies would require a drastic change in the structure, motivational pattern and way of life of present societies--an event which is considered 'subversive' by some, unrealistic by others. Let us briefly review the main criticisms.

To start with, there is the usual misinterpretation that the limits message purports that economic growth should be stopped everywhere, now--which is nonsense. This posture is alien to both

the MIT report and very definitely The Club of Rome, as the Commentary of its Executive Committee included in the book and some of our observations herein explicitly underline.

Once this point is clear, the question is asked whether millions of people in the rich countries would be willing to accept a cut in their living standard. The answer to this very reasonable question probably is that, in the past, many nations have given up their high standard of life (and much more than that) when under threat of war or natural calamities; and that, today, polarizing attention to material standards alone appears to many tantamount to diminishing the quality of life. One may infer that a better knowledge of the alternatives confronting our societies may pave the way to acceptance of different value systems apart from the merely material. Propensity to change is greater when the need for change is understood. It is not surprising that countries of both high industrial and population density have been more moved by the report than emptier areas of the world, and that studies on social change are particularly advanced, e. g. , in Japan.

Another objection concerns the possibility, or rather impossibility, to conceive of substantial economic growth taking place in the poor countries in a context of economic stagnation in the industrialized world. Admittedly, this is hardly imaginable, as would also be a cut in the standard of living in an industrialized country which would not cause severe hardship to the disadvantaged citizens of that country. However, this is not the recipe suggested. The hard fact to be faced, the study says, is that--if some growth limits are proven, or even if it is not disproved that they

do exist--mankind has to keep within such limits. And one may add that--if this demands that the value system and structure of society be changed--we had better use our imagination, all our political will, all our energies to make that change while still in time. If we are not able to do so, one does not see how this world--underdeveloped <u>and</u> developed--can go on.

A corollary criticism is that growth is an essential attribute of and condition for capitalism. But this affirmation is now disputed, even by no less a person than Jan Tinbergen, and it seems to equate capitalism with good--which is open to question. Similarly, the doubt is expressed whether the liberties of individuals and business could be preserved in the context of a no-growth world. This is again a double-edged question: optimum individual freedom for <u>all</u> can be but freedom limited by social responsibility--a limitation negative only in appearance.

In the same order of ideas, there is the contention that, since economic equalty is unattainable in this world, growth is its best substitute; thus stopping growth would imply perpetuating the existing inequalities in world income distribution. Whatever truth there is in this reasoning, it looks like a Machiavellian expedient actually to freeze the relative condition of the poor, who possess a lesser capacity to grow. We substantially question the premise, believing that there cannot be any long-term, structural substitute for reasonable economic equality (or at least equal chances) in the modern world. And we would recall a line by Christian Morgenstern, that "nothing can be that shouldn't be" (*).

(*) ".....dass nicht sein kann, was nicht sein darf".

We know that we have not touched upon all the major areas of criticism; but the discourse on this matter would be endless, and the hard fact remains that to accept a change of policies and even more of condition, people need to be convinced that the danger point is here; or at least want to know what advantages they can reap in the trade-off. For the time being, one may conclude with the thought that the future way of life, seen with the eyes of people conditioned by our rich, consumer societies, may look perhaps morally rewarding but a little bit austere; while seen with the eyes of the rest of mankind, it may look unbelievably plentiful. But in any event, the present way of life, seen in retrospect with the eyes of a future generation, will look incredibly disorderly and harebrained.

3.3.4 Criticism that 'More Important Problems' Exist

Of all the different critics advancing this argument, Carl Kaysen (*) has put it in the most articulate manner:

"How much does 'crying wolf' help to direct social energies towards improving our responses to these problems? To be effective, the cry must be well directed: the wolves must be imminent and they must indeed be wolves. On this score we can give only a moderate grade to ' limits', or more properly, to its sponsors in The Club of Rome. The problems they call us to attend are real and pressing. But none are of the degree of immediacy that can rightly command the urgency they feel. Indeed, at least two problems of worldwide

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(*) 'The Computer that Printed Out W. O. L. F. ', Foreign Affairs, July 1972, p. 660-668.

consequences outside the scope of this work seem to be more urgent than any it deals with: the creation of an international order stable enough to remove the threat of nuclear war, and the diminution of the staggering inequalities in the international distribution of wealth. A good sentry does not cry up tomorrow's wolves and ignore today's tigers".

This is a remarkable piece of elegant journalism. In our opinion, it is inspired by another deep-rooted tendency--that of focusing on symptoms and consequences (inequalities, worldwar threat) instead of referring to the underlying causes (inter alia, the impact of overwhelming growth on traditionally organized society). Moreover, as has already been explained, it is the very nature of the predicament that its problems are so critically intertwined that it is not possible to deal with any single major issue separately and in isolation. The habitual kind of linear, sequential thinking ('disarmament first' or 'economic growth first') is basically wrong,and cannot lead us out of the present colossal impasse. Just imagine waiting for the world to be de-nuclearized before attacking the problems of poverty, or vice versa. Nothing has such priority as to relegate the problematique as a whole to second place. All the issues have to be dealt with, or at least understood, in a coherent, systemic way.

Let us close this argument by a quotation from Forrester which is fitting to the point:

"Men with Maddox message are essentially saying: remove the economic restraints, allow growth to continue, and maintain the past trends until economic and social pressures sufficiently

threaten society that the latter alone stop growth. We see these social pressures increasing already. I believe we can clearly trace back to growth and to the changes that accompany technology such social disorientations as drug addiction, rising crime rate, aircraft hijackings, genocide, and the increasing threat of a third world war. A third world war is apt to involve conflict over space, natural resources, pollution dissipation rights, and political freedom. All of these pressures are intensified by rising population and by rising industrialization". (*)

4. The Growth Issue and Beyond

4.1 The Debate Under Way

The bitter and often utterly injustified criticism of the study has shown that a sore spot of society has been touched. On the other hand, after the first shock, an increasing wave of interest and assent from all strata of society confirms that the nature of man is not as stereotyped as some claim. But the most hope-inspiring fact and something indeed amazing is the serious and profound debate of the problematique which has gripped personalities of the highest responsibility in politics, business and science in many countries--which would not have happened had the report not concretized an intuitive disquiet. The debate has just started but it is gaining ground. Within only some eight months after the appearance of the report, an important change of attitudes can already

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(*) 'The Fledgling Cheermonger' by Jay W. Forrester, submitted for the January 1973 issue of the Cambridge Review, University of Cambridge.

be perceived. Incidentally, second-line people still show hostile intransigence when corresponding first-line people have already changed their attitude or have taken a balanced stand--a situation whis is paradoxical only at a superficial glance.

The panoramic overview permitted by the MIT study has changed the average outlook more than anything before. Even ordinary citizens feel that for the first time they have been given the possibility of seeing for themselves the continuously interlocking, tremendous world problems that threaten all peoples and nations regardless of the degree of their development or political regime.

While it is too early to take stock of the situation, it can be stated already now that the higher the responsibility, the greater the attention devoted to the universal problematique invoked. This is confirmed by some of the highlights of the growth debate given in Annex C, and the following sample reactions which cannot be attributed to specific persons:

= Our nations are caught in a vicious circle in which today's difficulties are to a large extent the result of past complacency, improvidence and neglect. But current problems and crises are so absorbing that most of our energies are engaged in facing them. Unable to plan sufficiently ahead to meet tomorrow's greater problems, we are all condemned to be prisoners of the past. This vicious circle gets steadily worse, and must be broken. The time has come to find how.

= The irony of modern society, so amazingly advanced in many aspects, is that it is not organized to tackle the very fundamental

questions where practically everything for everybody is at stake. People want to be effectively informed and to discuss with those politically responsible such crucial issues as the deterioration of the global environment for human life, the danger of over-crowding the planet beyond its carrying capacity, the overkill spiral in armaments, the Third World's growing lags in socio-economic and human development, and their possible worldwide effects.

= We begin to perceive that something fundamental has to be changed in the present way of conducting human affairs, in a world that has become unbelievably small and vulnerable, and are ready to accept that many of these changes cannot be brought about within the enclaves of separate, quarrelling nations.

= For the first time an instrument has been demonstrated which is to some extent in keeping with the complexity of our world and its problematique. Never again will it be possible to regard population, monetary matters, industrial growth and many other problems as autonomous areas of policy determination.

= The need for a new approach to science and technology has been shown to be an area which can no longer be regarded as autonomous in terms of policy. Unless research and development are initiated in a prospective sense, in awareness of social and economic trends and of problem growth, the dichotomy between human needs and technological development will get completely out of hand.

= The fallacy has been shown of the theory that the overall goals of a social system are best approached by working separately towards each sub-goal. On the contrary, in our present condition every effort to enhance one sub-goal reduces the chances of meeting other sub-goals. The problem is to determine the optimum compromise, not only at national but also at global level.

= In cost-benefit relationships among nations there has always been the tendency to realize the benefits in one place and have the cost paid in another. Now it has become evident that the benefits of economic expansion can be increased in exchange for a cost to be paid in the future. This is a dangerous trend. As a matter of fact, we are beginning to pay the price for advantages that mankind (or rather a small portion of it) enjoyed in the past. What will happen to our children if we continue along this path?

= One of the key findings is that a system which tries to accommodate rapid rates of material growth to a slowly changing institutional structure is fundamentally unstable and will undergo profound fluctuations. While no one can say with certainty what the ultimate cause or the precise timing of a major world crisis will be, there certainly will be one. This is true whatever the details of the model we may choose to study the modern world.

= If the book on the limits to growth is read carefully and with an open mind, it becomes clear that, despite the terms of the title, it is not growth as such which is at fault but the present kind of

growth and our methods of measuring growth.

It is sure that the debate presents the danger of polarizing extreme positions, that of apocalypticians and that of incurable optimists--both critical of, and rejected by, The Club of Rome. On the other hand, the debate under way, however confused, is the strongest catalyzer of a new awareness of the trends and interactions going on by our own impetus in this planet in which many more generations have the right to live.

4.2 New Guideposts Emerging

We have pointed out that the MIT project, the first in The Club of Rome's series on The Predicament of Mankind, was conceived as a commando operation, and that its tactical success was expected to trigger off strategic consequences. This purpose has been fulfilled. Apart from its intrinsic merits, the 'limits' study has in fact the merit of having opened up a new dialogue. The debate we have just reviewed is due to the widespread commotion, the new consciousness and the movement of opinion it has created. Considerations which go far beyond the mismatch which exists and grows between an ever-expanding and demanding humankind and the finite nature of our planet are now being made. Unmistakably our Earth-bound species has to watch its own growth on it--unless it wants to trust its future to the exploitation of the cosmos and the 'greening' of the universe. But the growth issue should not monopolize our attention.

Other parts of the mass of problems confronting world society are

as deadly important, and as urgent. To embrace all of them a substantially higher plateau of vision and comprehension must be reached, a quantum leap made in our overall theoretical and positive thinking. This escalation will require time and probably a concerted, joint effort by the entire world community. But already now public opinion has been awakened, and will help to find new responses to the unprecedented challenges it begins to perceive. One can see people of different condition and conviction trying to detect what reliable points of reference and guidance will finally emerge from the present confusion and turmoil. We submit that, even pending deeper research and meditation, some of these points are already within sight as they are so clearly inherent in the unprecedented realities of our epoch.

One such emerging guidelines is that global strategies and covenants for the use, allocation and management of critical non-renewable resources of the planet have become indispensable. The day is not far away when the world community must seriously set about conceiving and organizing these strategies. This may be done at the initiative of a group of particularly interested countries--e. g. the major user nations and those which by geographical chance control these resources--or preferably by a more widely-based international body. Among the critical resources that sooner or later, and for one reason or another, will have to be considered, are probably natural gas and petroleum, copper, mercury, lead, uranium, platinum, some 'exotic' metals, and gold. But, once this principle has been adopted, it may well be discovered that other rare or strategic materials had better be added to the list soon, and that similar criteria of global management are becoming inevitable also

with respect to climate, outer space, the oceans, possibly energy in a general sense--and in the end fertile soil as well.

A second firm norm one is forced to accept at this stage is that of the collective responsibility of mankind for the good management of the Earth's biosphere--not only limited to the species which directly serve human needs. There is already a growing awareness that the human creature must acquire greater ecological sensitivity and wisdom if it is going to fare better, or even survive biologically, among the other living forms. Other swift steps must however be made in this direction to avoid further irreparable damage. Though from an anthropocentric viewpoint the other animal and plant life manifestations are of a lower hierarchy, it is the interplay of all their myriad cycles and systems which provides the polyform, integrated texture of life that some hundred thousand years ago created homo sapiens and still now is at the basis of his very existence. His folly is becoming clearly apparent when he exterminates species after species or disrupts and degrades their ways of life for ephemeral reasons of greed, comfort or expediency--which is precisely what we all are doing at an increasingly massive scale.

These two basic norms call for the definition of a new set of disciplines, together forming the earthkeeping sciences. In writing this paper, it is our hope that Europe, which perhaps needs them to be recognized more than any other region of the world, will take a lead in devising adequate approaches for their systematic elaboration and diffusion.

Another and partly consequential guidepost which, though in the face of much opposition, is gaining recognition is that the human species

cannot go on growing, exponentially or otherwise, beyond certain limits in this finite planet. We have discussed this. Even the die-hard optimists, who argue that human presence and activity can still find ample space and opportunity to expand without worrying too much for the time being, cannot of course claim that such growth can be indefinite. Some limits must exist somewhere. The perception that this is a hard fact is getting stronger. And it is increasingly being realized that it is now urgent to discover what these limits actually are, e. g., for a certain region to enjoy certain standards of life, including quality of life, over time, considering its own resources and capacities, and its relationship with and possible encroachment on other regions faced by similar alternatives. The sooner these assessments are made, the better our collective chances will be for the future.

Let us be permitted to note in this context the unfair posture of those critics who, contesting that mankind is approaching boundary conditions in its occupancy and exploitation of the Earth, denounce their opponents for the sin of advocating a chimeric, but stagnant and decaying 'zero society'; or 'zero demographic or economic growth', and 'zero effluence or pollution' <u>now</u>. In our view such 'zero goals' would again--though in reverse--be an expression of a conception of life which regards human fulfilment and destiny in purely or mainly quantitative terms. Unfortunately, the 'myth of growth' still prevails. But the crude, outdated, purblind addiction it engenders is so unfit for the new world shaping up that it must and will disappear--the sooner the better--although we are not so naive as to believe that the transition will not be turbolent and painful, or that it can be engineered now.

Needless to say, on the other hand, just because society is at present so committed to growth nobody in his senses can dream of successfully launching 'zero growth now' policies. What is needed, now or in the very near future, is instead a proper understanding of where in broad terms the present growth syndrome may lead society, so that it can liberate itself from its spell and be free, for its further ascent, to seek values, motivations and goals consistent with the changing reality of this period of metamorphic transition. We want furthermore to state that it is particularly up to us living in advanced industrial countries--at the forefront both of knowledge and affluence--to feel it a moral obligation to get rid of the material wealth obsession we inherited from times of scarcity which are no longer with us. In saying this we are again thinking of Europe and the role it may have in the embattled and doubt-torn modern society. It behoves perhaps Europe to take the initiative, to find ways to humanize growth, to make it selective, oriented, governable, introducing such qualitative changes as may permit the attainment of different, more complete degrees of wellbeing.

These are just the first guideposts looming up in a sequence of milestones on the path to a new phase of evolution of the human system. To become a responsible and mature society, that has to be in harmony with its habitat, well-balanced with respect to the natural systems which support and condition it. The expanded and thriving community of man foreseeable for the coming decades cannot ever expect to flourish, or even be secure on its planet, if it remains in a grave or permanent state of disequilibrium with its environment. Nobody can yet define what such a condition of equilibrium or 'stable state' should be, although we can imagine .

that it could perhaps be not dissimilar to the dynamic, ever-changing and ever-adapting ecological equilibrium of living things. Man, who in his arrogance conceived of himself as a godlike supreme master of the Earth, will have now to seek the way of his terrestrial salvation by seeing himself instead--as he indeed always was--as part and parcel of Nature, and be at peace with it. The fuller this recognition and the better this ecological balance, the higher our quality of life and the greater our individual and collective options for the future will be.

Finally and logically, in the stride of these conceptual developments, though less clearly as yet, another basic norm will have to guide our positive thinking. External equilibrium between society and Nature, however indispensable, cannot be attained, or if attained would soon be disrupted, if society itself is in a state of internal disequilibrium. In point of fact, technological society needs social justice and peace more than any society of the past. In an age of exalted human power and extreme alternatives, social justice and peace not only conserve their primary and lasting ethical value, but turn out to be a matter of great political consequence, ecological concern, and existential significance. Further increases of population, economy and technology will but accentuate this interdependence. And whatever our relative growth restraint and environmental balance, whatever sort of good management of our lot on Earth we can provide, human society will be constantly in danger unless and until the present intolerable disparities between rich and poor, between educated and illiterate, between those who have all the chances life can afford and those who haven't any are eradicated, or at least fundamentally reduced.

Considering the growth issue in this light will help us to appraise it more intelligently and place it in the context of the world problematique. It will then be clear that, even if the offerings of science and technology were boundless, they could not, alone, underpin mankind's growth, make it fully rewarding or acceptable. Certainly society cannot be de-technologized; on the contrary, techno-scientific progress will continue, and may become even swifter. But the very developments that can be imagined--for good or for evil--in the information-communication technologies, in computer technology, in harnessing new energy sources, in controlling and using the climate and outer space for human needs, in human engineering and genetic moulding, and in so many other fields, compel us to match and control them by equally advanced political, social and generally cultural developments. A society that wields more power than reason will remain a barbaric society.

To avoid this degenerative involution, our main effort must be in the direction of social inventions and innovations. For one thing, new institutions are needed--most of them of global jurisdiction, such as those for managing critical resources, as already mentioned. But throughout history the inertia of the institutional setup, whatever this might have been, has always weighed heavily in the evolution of the human system in the face of changing situations. Nowadays, with rapid and radical change everywhere, this drag may have disastrous consequences. If imaginative solutions in our institutions and instrumentalities are not devised quickly, disastrous breakdowns and revolutions have to be expected.

The major obstacle to innovation in this field--and one that hardens

the entire world problematique across the board--is represented by nothing less than the nation-state, outdated but sovereign, unadaptive but strongly entrenched. It is, then, the concept, nature and myth of this basic unit of human organization which needs to be transformed, complemented, diluted in accordance with new world realities (*).

4.3 Further Research

The reality and validity of the pillars of new wisdom just mentioned must be thoroughly questioned and assessed. Their merit for the moment, however, is to evidence how radically different from the traditional wisdom, which in various ways has guided civilization till now, the new wisdom must be that can offer mankind a sporting chance to override challenges and threats that for the first time are of global proportions. Various alternative courses are open, but the danger of miscalculation is enormous. And moreover, the pressure and complexity of new situations building up may push certain human groups to risk shortcut solutions by the logic of force, which may climax in a truly catastrophic Battle for the Earth-- in which humanity and everything else may be lost.

We have already mentioned that the first response should be a joint endeavour to gain a true, comprehensive understanding of the changed human condition and the choice of options open to the community of man. This calls for a blend of research, reflection, insight and

(*) We would like to suggest, as reading matter for meditation on this general subject, a working document of 'Le Groupe des Dix' prepared "with a view to answering The Club of Rome" (Paris, November 1972).

creative imagination. For its part, The Club of Rome has promoted a series of 'second generation' studies in Europe, Japan, Latin America and the United States. Some of these will be disaggregations from the initial world model, others will go deeply into parts of the system, such as the population-food-agricultural interfaces or materials availability on a global scale; others will attempt to evolve different methodologies for investigation on the world system; yet others will analyze in depth the problematique. In this paper, we will limit ourselves to touching upon two of these new projects which, although still dealing mainly with the material aspects only of our collective life, are a step beyond the first growth appraisal made at MIT.

The first of the two projects, tentatively called Strategy for Survival,(*) is based on a model that recognizes the specific characteristics, standards and dynamics of the various regions in the world, and hence breaks down the total system into interdependent regional subsystems which increasingly interact among themselves. Although the world problem situation is generally viewed by these regional systems as one of crisis, each of them is conscientiously engaged in seeking solutions exclusively or mainly to its own problems only. This response to challenge is simulated by the model, which attempts to represent explicitly the goal-seeking and adaptive nature of the human system, whose efficiency however is hampered by its fragmentation and by time-delays in problem recognition and the organization of remedial action.

We expect that this project will lead us to rediscover the old, sobering truth that, due to human shortcomings, society's limits to growth are

(*) Since some progress reports have already been prepared, their authors, Professors Mihajlo D. Mesarovic and Eduard C. Pestel, are prepared to make them available.

in fact narrower than the world's physical dimensions; and also to realize how inextricably all nations and peoples have become bound together, none of them any longer being able to escape a fairly common destiny. Solidarity must supersede rivalry.

The second project, called Problems of Population Doubling (*) attempts to explore critically whether and how, or rather under what conditions, it will be possible to lodge, nourish and provide with the other necessities of a decent life the swollen ranks of humankind--which according to current estimates will double its size in a little more than thirty years. The problems and dilemmas created by this doubling of the world population in such a short time, aggravated as they are by ill distribution and rapid urbanization, are simply frightening. Just take the Herculean task of preparing the necessary infrastructures--from houses, schools and hospitals to industries, harbours and roads, and the new lands to reclaim. To perform it, our generation has to do, by itself, a construction job equalling in size all that mankind has built since man ceased to roam about in the wilderness and started to create his first settlements. And the attendant job of rationally using the scarce land available for this and the other human needs will pose planners in most countries well-nigh insoluble problems.

But, of course, the question is not only one of growth--how to multiply the production of infrastructures, food and goods in an orderly manner. Other questions will weigh heavily on our capacity and imagination. Besides providing twice as many citizens on the planet with adequate

(*) Further indications can be given by the project director, Professor Hans Linnemann, or advisor, Professor Jan Tinbergen.

housing, nourishment and products, will it be possible to guarantee them reasonable sanitary facilities, health services and access to education? Can these production levels be attained in view of ecological dangers and resource exhaustion? Can this effort be organized with the general participation of all the world's inhabitants, without leaving aside, as is now the case, hundreds of millions of 'marginal' men? Can all this be done without impairing the possibility of satisfying further human needs, should the world population continue to grow later on? What new institutions, instrumentalities and approaches will be needed to mount this global undertaking? To be sure, the study will not try to answer all these questions, even in a preliminary way, but they will be kept ever in the forefront while it is being carried out, and consideration will be given as well to the fundamental difference as to the needs and solutions which are most appropriate for the have and have-not parts of the world.

To this effect, the total system will again be broken down into its different, though interlinked, regional components, and the productive activities will be studied with various sets of criteria--according to whether or not they permit recycling or substitution of materials, and what degrees of technological sophistication they require. We anticipate that this study will show that the present industrial and productive establishment of the world, and its structures and modes of operation, are grossly inadequate to respond to the tremendously stepped-up demands of a doubling society. They will therefore have to be progressively reorganized, rationalized and relocated on worldwide bases according to long-term, overall designs--quite a revolutionary idea, to which however we had better start adapting right now if we want to coexist on Earth as decent human beings.

A Word of Conclusion

To conclude, our true understanding of man and his world in the technological age has so far made just a few faltering steps. The authors of this paper believe that the MIT research, its shortcomings notwithstanding, cannot but be considered decidedly meaningful, and hope that subsequent Club of Rome studies will equally be so. They also feel they must underline that the world establishment, and more particularly its main power centres, have failed to recognize the real nature and magnitude of the new challenges confronting mankind, and that even in the questions of growth of our immediate interest they have shown a marked unwillingness to face the whole picture, preferring to take refuge in the analysis of details or peripheral aspects. It was left to a little book to raise the issue.

Now this question and many others of general import are before us. If we, both government and citizens, persist in shutting our eyes to what is new in them, indulging instead in wishful thinking, the old Chinese curse--"may change strike you"--will indeed strike us. On the contrary, it we are alert and try to understand what changes are under way and what they mean, and prepare to meet them adequately, then we can soar above our difficulties--showing yet again that man's finest hour is in adversity.

Annex A

Working Papers Available from System Dynamics Group Massachusetts Institute of Technology

Behrens, W. W., "The Dynamics of Natural Resource Utilization", 10 pp. (1971). The dynamics of natural resource utilization and the effects of substitution and technology on that usage.

Forrester, Jay W., "Counterintuitive Behavior of Social Systems", Technology Review - Reprint, 16 pp. (1971). An introduction to the nature of social system behavior and the techniques developed at M. I. T. Illustrations drawn from the World Dynamics Model.

Forrester, Jay W., "Counterintuitive Behavior of Social Systems", Hearings Before the Ad Hoc Subcommittee on Banking and Currency, U.S. House of Representatives, Part 3, Reprinted from U.S. Government Printing Office, 65 pp. (1971). Similar to the Technology Review Article, but including transcripts of discussion, and three appended papers:

Forrester, Jay W., "Systems Analysis as a Tool for Urban Planning"

Forrester, Jay, W., "Toward a National Urban Consensus"

Christopher, Michael, "A New Approach to Economic Analysis", from Finance magazine.

Harbordt, Steffen C., "Linking Socio-Political Factors to the World Model," 42 pp. (1971). An analysis of the Changes in the world model needed to include socio-political factors.

Meadows, Dennis L., "Preliminary Draft, Phase One, Dynamics of Global Equilibrium" (Ottawa Presentation), 104 pp. (1971). A description of the World Project including summaries of all the related substudies undertaken.

Meadows, Dennis L., "Testimony Before Senate Subcommittee on Air and Water Pollution in Support of Senate Bill 1113 - The National Environmental Laboratory Act of 1971," 20 pp. (1971). A statement stressing the importance of long-term problems in our national priorities.

Meadows, Donnella H., "Dynamics of Population Growth in the Traditional Agricultural Village," 24 pp. A study of the forces that determine population trends in a typical agricultural village community. This paper is an extract from the proposal of a project still underway.

Meadows, Donnella H., "Testimony Before the Education Committee of the Massachusetts Great and General Court on Behalf of the House Bill 3787," 17 pp. A statement supporting environmental education in Massachusetts.

Milling, P., "A simple Analysis of Labor Displacement and Absorption in a Two-Sector Economy," 15 pp.(1971). An analytical model of potential impacts of labor productivity increases in a predominantly agricultural economy.

Naill, R.F., "The Discovery Life Cycle of a Finite Resource - A Case Study of U.S. Natural Gas," 50 pp. (1971). A study of the forces controlling supply of a finite resource and the effect of policies such as regulation on that supply.

Randers, J., "The Carrying Capacity of our Global Environment - A Look at the Ethical Alternatives," 22 pp. (1971). A look at growth in a finite world and the importance of long-term equilibrium. Paper delivered at World Council of Churches, Nemi (Italy), June, 1971.

Randers, J., "The Dynamics of Solid Waste Generation," 79 pp. (1971). Understanding the nature of the solid waste problem and its possible solutions, including recycling effects.

Randers, J., and Meadows, Dennis L., "System Simulation to Test Environmental Policy: A Sample Study of DDT Movement in the Environment," 50 pp. (1971). An examination of the effectiveness of Environmental policies such as control of DDT.

Annex B

Some Criticisms: Point and Counterpoint

1. The Assumption of the Model

Demography

Criticism	Answer
Birth rates have been falling in almost all countries (Maddox)	Death rates have been falling even more, in particular in the 'developing' countries.
In the Western world a certain adjustment of birth rates to death rates is found ('demographic transition'); the 'developing countries' will follow as they become wealthier (Maddox)	Available evidence shows that lowering infant mortality increases the population growth rate in the short term, with beneficial effects through lowering the fertility rate following only after several decades. There is doubt as to an increase in wealth in the underdeveloped world as fast as the increase used to be in the now industrialized countries. Moreover, decline in birth rates historically has followed industrialization only after a substantial time lag.
Demographic transition in underdeveloped countries may be achieved independently of increase in wealth by special birth control measures	There is no evidence to sustain such a thesis, considerable for the contrary. But if there were and if family size dropped precipitously in underdeveloped countries so that by around the year 2000 reproduction would reach replacement level (and no competent demographer thinks there is the remotest possibility of this occurring), the size of the population of a typical such country would be 2.5 times its present size when it eventually stopped growing. This is

caused by the age structure: more than 40% of the population is under 15 years of age.

Although the population is rising at an exponential rate, it has not as yet reached the globe's carrying capacity and there are mechanisms in the system which are not included in the model (as they were not operative during 1900-1970 and thus not observable by Forrester-Meadows) which will cause the population to approach the carrying capacity asymptotically from below. (World Bank)

It is rather risky to rely on the hope that "there are mechanisms" when there has been no evidence of them during the last 70 years. But more important: the 'carrying capacity' of the planet is not known; it is at any rate not a fixed value but decreases with depletion of non-renewable resources and with increase of the consumption rate per capita; moreover, it varies with cultural and behavioral factors. So if, as we all hope, the long-term carrying capacity of our planet has not yet been trespassed upon, reduction in population numbers and in average consumption would prolong the journey of mankind on this spaceship. Doesn't one use the brakes <u>before</u> hitting the obstacle, in particular when billions of other (if future) human beings are concerned?

Food

Criticism	Answer
There is a food surplus in many regions of the world.	Yes. But about two thirds of mankind is underfed, mainly affected by protein deficiency (UN Food and Agriculture Organization).
Since the late nineteenth century we have multiplied the amount of irrigated land by four to five times, and will see another doubling before the end of the century.	True (perhaps). But despite these enormous accomplishments, the amount of land man has turned into deserts by overgrazing and over-pressure is (perhaps) about five times greater than the amount we have irrigated. In India one quarter of the entire acreage has such heavy erosion that the topsoil will be gone before the end of the century.
The 'green revolution' is expected to produce a fairly rapid improvement in production of cereals.	"The drive for higher yields cannot continue for very much longer because of ultimate shortages of water and fertilizers. But there is a reasonable chance of managing it for the rest of the century. However, that is only under one assumption: that we move to strict population control now, in the 1970's. We have to, because we are already on the verge of the unmanageable". (Norman Borlaug, awarded Nobel Prize for his merits in the 'green revolution'). Besides this, the 'green revolution' necessitates an efficiency and intensity of agricultural effort beyond the possibility of a peasant economy and thus gives rise to social difficulties, flow to the cities, etc. And the ecological consequences have not yet been fathomed.

4.

What about food from the sea?

"The claims have been very exaggerated. The oceans look vast, but we forget they contain large desert areas. We can perhaps double the world's catches, and possibly treble them. It is questionable whether we can double the catches without gross over-fishing. But the most basic point about using the oceans to feed the hungry is what we do with these fish catches today. Approximately half of them go into the feeding troughs of Europe and North America for animal production, primarily broiler, chickens, eggs, white meat and milk." (Borlaug). Furthermore, life itself in the oceans is in danger, and the situation is certain to become worse before it can be improved and uphold the hopes of harvesting large quantities of food from the hydrosphere.

What about synthetic food?

This is a possible, but not yet feasible way to ease the situation. It takes probably decades to develop and implement;and the use of non-renewable resources (fossil fuels?) as well as energy must be taken into account.

"We must stop thinking that there are easy solutions to these fearfully complex issues. People go around saying we have a solution in food from the seas, in synthetic food, in land reform, in irrigation. It is not like that. Let us be realistic about this; we are not going to remove all hunger. All we can do, if we are sensible, is reduce it below a danger point. As it is now, it is moving rapidly to a very grave universal crisis". (Borgstrom).

Resources

Criticism	Answer
The estimate confidence level of the US Bureau of Mines data (main information source of MIT) is relatively low: 80% of the estimates have a confidence level of less than 65%.	True. Better data are difficult to find. Therefore the values used have been arbitrarily chosen five times the presently known resource date (500-year supply of all resources, at 1970 usage rates).
Even 5 times increase of the reserves over the next 100 years seems unduly conservative in the light of recent finds and underwater sources (World Bank)	This may be true for iron ore, aluminium, manganese, cobalt and other minerals. For copper the source cited by the critics gives estimates of twice the exploitable resources at 200% cost increase for 'conventional' origin and a 25% reserve increase by sea-bed extraction. Nickel seabed resources would permit a production corresponding to 3 times the present Western hemisphere value. As to aluminium, a 200% increase in price would make it possible to use clay which is virtually inexhaustible; however, this would entail the use of large quantities of electrical energy which may or may not be easy.
Lowering the demand growth rate from 4% to 1.5% would correspond to a lengthening of the "life" of the resources by a factor of 5. (World Bank)	Lowering of resources input into industry (for equal output) by a factor of 4 has been assumed in several of the model runs.
We do not know the true extent of the resources that exist in, and can ultimately be recovered from, the earth, nor will it be known in the next two years or ten years (World Bank)	Right. That is why the study had to work with assumptions, in order not to wait for another 10 years. More studies on resources are, of course, needed.
To argue that no amount of research or technological breakthroughs will	To argue that research or technological breakthroughs will extend the lifetime of

extend the lifetime of resources indefinitely. . . . is mere intellectual fantasy.

resources indefinitely is mere intellectual fantasy. Technical progress could, however, in a number of cases extend the effective life of a number of critical materials considerably. The whole point of the report is to pinpoint the difficulties, in order that such research should begin now on a number of critical issues because the development process is very lengthy (upwards of 15 years) and the real question is: Have we time?

Energy can be much more economically used. There is scope for smaller cars with weaker engines, public rather than private transport, increasing efficiency in burning fuels and in generating and distributing electricity, and improved design of aircraft engines and bodies (World Bank)

The study assumes unlimited availability of energy. But one must agree that there is scope for great economies in the use of energy and in the improvement of efficiency in energy production. Again it is a matter of beginning to look at these things seriously. The assumption of the study that energy is limitless is perhaps one of the weaker points of the report, especially in view of the probability of an energy crisis over the next twenty years owing to scarcity of petroleum and natural gas. The phasing-in of fast breeder reactors and massive utilization of thermal, in particular high temperature reactors, is still terribly uncertain. The provision of sufficient energy is a quite critical point in relation to the use of technology to increase the time for manoeuvre.

It is not a question of expecting natural resources to accommodate forever our current patterns of growth, production and consumption; clearly, they will not. But we are confident that natural resources will last long enough to allow us time to make deliberate adjustments in our manner of using natural resources in such a way that resource needs can be met indefinitely (World Bank)

Such problems have, unfortunately, up to now really been a matter of confidence not of enlightened judgement. Studies are therefore needed on the question of when adjustments are needed, how far-reaching they have to be, of what potential type, and what potential side effects they might be. It has been one of the objectives of the report to attract new attention to the necessity of adjustments and in particular to the time element involved.

Resources are properly measured in economic, not physical, terms; new mineral resources can be created by investment in exploration and discovery.

This is the traditional economist's argument that economic forces create R & D and innovation. True, they do so, but often too late; moreover, no miracles should be believed in. "Our traditional reliance on research and programs to increase our resource base will be of little avail, nor long lasting" (Russel Train, Chairman of the US Council on Environmental Quality). Finally, the assumption of resources corresponding to 500 year supply, at 1970 usage rates, already takes considerable investment in exploration and discovery into account.

•

The weakness of the computer is characterized by the famous GIGO principle: garbage in, garbage out.

A computer memory filled with garbage is easily cleared, not so, unfortunately, the brains of people. Some may even never have learned anything of importance and still rate happily along: nothing in, garbage out (NIGO principle).

Pollution

Criticism	Answer
If we were to continue to rely upon fossil fuel for energy production, severe environmental problems would arise (mostly, of a local or regional character), and pollution control would be costly. Eventually, the accumulation of atmospheric CO_2 might prove intolerable, and the further use of fossil fuels would have to be foregone altogether. If, instead, we were to alter the energy production process to rely mainly on nuclear power, we would encounter very large problems of plutonium management, radioactive waste disposal, and reactor safety. Construction of hydroelectric dams also causes severe environmental hazards. In these respects, there is merit in the argument that rapid growth can endanger clean environment unless appropriate long-run safeguards are adopted. By the same token, however, over a time span of decades, fusion power, solar power and the use of hydrogen-oxygen fuel as replacement to the internal combustion engine could drastically alter the pollution problems associated with energy production (World Bank)	The very feasibility of fusion power is not yet proven, eventual economics utterly unknown. Some pollution and waste problems caused by fusion neutrons, uranium blankets and certainly from tritium would show up even with this technique. Fusion would be on the market well after the year 2000, if ever. Solar energy cost is presently estimated (by its promoters) at ten times the 'conventional' value. There are space and storage problems as well as narrow climate limitations. At any rate solar energy cannot probably become of global energetical importance before the end of the century. As again it may be the time factor which could become decisive, an example for substitution delays in the energy field may be interesting: nuclear fission reactors were invented in 1939, proven feasible in 1942, first power use in 1953, commercial in 1966; now, 33 years after their invention, nuclear reactors produce about 3% of electricity, 0.7% of primary energy; it is hoped to produce about half of the electricity by nuclear means by 1990, but not more than 15% of primary energy (50 years after the experimental demonstration of feasibility and with some hundred billion dollars spent on R & D, partly military). Hydrogen may indeed be a good alternative for car engines and many other applications. Production with nuclear energy is possible, although today utterly uneconomic; production efficiency would be about 25% using electrolysis, about 40% using hypothetical processes under development as compared to about 90%

for production of refined products from fossil raw materials. At any rate fossil fuel substitution by hydrogen would constitute a considerable increase in nuclear energy use as a primary source, with corresponding environmental problems of reactors, nuclear fuel cycle and waste storage.

The model assumes that there is a limit to the amount of pollution the world can absorb in a year and that this limit is four times the pollution now produced annually. There is absolutely no scientific evidence to support such a conclusion. Progressive pollution levels may destroy present concepts of living during the next 100 years, but the model builders marshall little scientific evidence to prove it will destroy life itself (World Bank)

At the present status of knowledge the assumption used could not be more than an 'educated guess'. The report makes clear that its consideration of the pollution aspects is fractional in that it concentrates exclusively on the accumulation of products which are non-biodegradable or decompose very slowly (e. g. DDT and mercury). Possibly the ecologists are just alarmists, although their fear of an overall deterioration of living conditions can point to quite a few tragic examples that have already occurred. We just do not know enough, and it is very necessary to undertake long-term research on these matters immediately so as to have some real facts as a basis for action and a means for rationalizing hysterical anxiety.

Technology

Criticism	Answer
A sufficiently large and exponential increase in technology will solve all food, resources and pollution problems.	The answer is complex. Basic arguments against this thesis are already given in many of the above points. In general, it may be said that the 'optimistic' critique of modern variants of 'Malthusian' arguments rests on the belief that the steady technical progress of the past century or two can be extrapolated into the future, and be directed towards new goals with equal efficiency, staving off potential catastrophies. However, this optimistic assumption may itself be vulnerable because of systematically diminishing returns to investment in science, technology and education, as indicated in the paper. Moreover, the net useful output of new industrial techniques will become relatively smaller with the need to devote an increasing part of the effort to remedying the unwanted consequences of primary techniques (pollution, degrading of nature, congestion of cities, fertilizer and pesticide effects, etc.). With the limitations to the possibilities of technology, what is needed is not the haphazard, extemporary, if not military-oriented advances we experience now, but a set of science policies globally coordinated to attack the bottlenecks and weak points endangering our overall situation. But this rational use of our expanding knowledge is still a far cry. Technology's creations still obey private or sectoral interests, not the general one.

2. Imperfections of the Model

Criticism	Answer
The model has a very high level of aggregation. Averages of very dissimilar variables have been taken, a procedure which can give extremely misleading results. Also the number of feedback loops is rather low. (World Bank)	It was acknowledged from the very beginning that the first study is of a 'pilot' nature and that there would be inherent difficulties in interpreting the results in terms of real circumstances in different countries or different subassemblies of aggregated parameters. As to the fear of misleading results, detailed studies under way will show whether the way in which the 'averaging' and aggregation has been done really affects the general conclusions. The feedback loop system will assuredly be perfected in later model generations. Critics and criticised alike should endeavour to 'de-bug' the tool.
At least a 'two-world' model is needed in order to distinguish between the 'developed' and the 'undeveloped' parts of the world.	This belongs to the 'second round' studies now under way as indicated in the paper. Lumping together so many different countries in one camp or the other would however be equally misleading. Further disaggregations must be made as soon as reliable statistics and other data are available.
A major flaw in the analysis lies in the total absence of adjustment mechanisms of any kind in the model. That is not how real social mechanisms work. Especially in the working of the economy, adjustment mechanisms play a crucial role. The most important of these is price (World Bank).	Some adjustment mechanisms (like birth rate as a function of GNP) have been introduced, but rather few. As indicated in the paper, real social mechanisms do adjust rather insufficiently, at any rate with a very long time lag which has turned out to be too long with respect to modern growth and change rates in research, technology, industrialization and urbanization, for in-

stance. No adjustment mechanism has prevented the untenable situation in world nutrition, in private transportation, in the cancerous growth of metropolitan areas filled with misery, in the extreme disparity of wealth among countries and within countries. And price is no longer a valid regulator in many fields; it is often established by factors overruling the demand/supply relationship.

In the case of industrial capital, the rate is defined as output less consumption, agricultural investment and services investments -- in a sort of residual theory of investment which is not in accordance with any modern theories of investment. Moreover, the average lifetime of capital should not be constant but rather a function of level of development and the rate of growth (World Bank).

For a given output, considering investment in agriculture and services of vital importance, the freedom of choice was between consumption and industrial investment. In the model runs which assume no drastic change of policy and behaviour, the present propensity to invest industrially and average lifetime of industrial capital stock have been considered. In some other runs, supposing different policies, the rates of investment and the stock lifetime have been modified to suit a more equilibrated behaviour of society (e. g. longer equipment and product lifetime). It is important to note that pollution abatement investments have to be made besides industry, in the other categories as well: services (e. g. traffic, pollution), agriculture (e. g. fertilizer pollution), and consumption (e. g. household pollution from heating, detergents, etc.). However, more sophisticated investment and capital lifetime hypotheses will have no doubt to be applied in future investigations.

A fairly serious objection can be made about the question of reversibility. . . Since virtually all of the relations of human behaviour with respect to income level have only been observed on the way up, the model is seriously in error to assume symmetric behaviour. . . Data shows that as income rises the birth rate falls, and this is incorporated directly in the Forrester

This is another field in which ameliorations are certainly worthwhile. A partial approach to this problem has already been realized in the original model using mechanisms of 'third order' delays.

As to the example of birth rate as a function of income there is considerable evidence that factors such as instruction and habits are less important than the degree in which al-

model and indirectly in the Meadows one. One would expect, however, that on the way down with income the birth rate would not go back up the curve, but rather would remain at very low levels perhaps going up only when income reached low levels or when enough time had passed so that the high income habits of low fertility had been forgotten (World Bank).

ternative modes of personal gratification exist which in modern societies are usually linked to income. The problem is thus not so much one of reversibility but of determining and qualifying psychologically relevant factors, which are insufficiently known as well as their influence on industrial and social behaviour.

A model is sensitive to changes, such as the inclusion of small exponential rate in the discovery of natural resources and pollution abatement techniques, rather than using linear or step functions.

This is true. Such inclusions (with the same 'time integrated content' as the linear or step functions, for a certain period of time) may in fact change model behaviour from 'collapse' into a milder crisis. It should be investigated which of the two modes corresponds more to reality.

The level of detail in the different sub-systems of the model is uneven.

Future disaggregation of the initial model and the replacement of major variables by distribution functions will show the relevance of this imperfection. This and other criticisms should be addressed to be body of information presently available on the problematique and attendant phenomena, rather than to the model of the MIT exercise.

The world is finite, thus it is impossible to expect the population of the world to be able to grow exponentially without stopping, or without something eventually preventing exponentiality. This is an obvious point. Malthus told us this in 1798; he did not need the MIT computer.

True (but arrogant). Comment: That Malthus did not need the MIT computer is irrelevant. He did not have it at his disposal. Wouldn't he have liked to know more about the dynamics of the 'world system' and, about the relative importance and the interaction of various parameters?

3. Presumed Remedial Policies

Criticism	Answer
One is not talking about something within the scope of human experience that millions of people will willingly accept a cut in their living standards.	Many countries have in the past considerably reduced their standard of life (and much more than that) when under threat of war or natural calamities. But even independently of exceptional periods: restricting attention to material standards of living alone appears to many already as diminishing the quality of life. Social aspects were deliberately excluded from the first study; and their consideration would in fact make the picture at once darker, but at the same time pave the way for acceptance of different value systems away from the merely material. It is not surprising that countries of both high industrial and population density have been more moved by the report than emptier areas of the world. Future studies, including some already begun in Japan, are concentrating on the social issues since it is fully appreciated that the attitude of individuals in societies will inevitably greatly influence demand for or rejection of the type of policy solutions suggested by the report.
It is difficult or even impossible to conceive of continued substantial economic growth in the poor countries in general taking place in a context of economic stagnation in the industrialized world.	Withing the present framework, it is impossible. We have to use our imagination, all our political will, all our energies to change that framework. If we are not able to change the framework one doesn't see how this world-- underdeveloped <u>and</u> developed -- can go on.
A cut in the standard of living, even in an industrialized country, will mean severe hardship for the disadvantaged members of society.	Correct for a truly capitalist society. May one then ask whether a society with material profit as its main motivation can find a place in a homeostatic world, anyway? This does by no

means imply that communist countries, as they exist today, could easily change direction versus an 'equilibrium society'.

Growth has been an essential attribute of capitalism since its conception in the late Middle Age, and it is questionable whether the liberties of individuals and business could be preserved in the context of a no-growth world. (Leonard Silk)

It is. In the past, individual freedom has proved to be a good slogan to implement and maintain slavery and exploitation, giving every possibility to the strong, the reckless, and the privileged, leaving the handicapped, the morally inhibited and the underprivileged open not only to arbitrariness but even to contempt. What of today? Equal freedom for all should be our goal. But optimum individual freedom for all cannot be but freedom limited by social responsibility, a limitation negative only in appearance.

'Profit' is the essential motivational force of man.

It gave rise to the Divina Commedia, the Ninth Symphony, the Monna Lisa, and polioserum. It really did! Only the kind of profit in these cases has been essentially non-material satisfaction, the respective incentives being cultural, spiritual or social. The whole concept of 'profit' must be revised, and its different kinds placed in a different order in the scale of social values.

If growth is "a substitute for economic equality", then stopping growth implies freezing the existing world distribution of income (Wallich)

If growth is a substitute for economic equality, why not substitute the substitute by the real thing? The carrot swinging before the nose of man may prove to be more perturbing than Damocles' sword.

'Limits' predicts hell in 50 years. Hell is already present on Earth in places such as Calcutta.

No comment.

Note: This point and counterpoint analysis is largely unprofessional. The authors apologize if they have misinterpreted some of the critical observations listed here, or omitted more relevant ones or given irrelevant answers. Their purpose was not one of rebuttal. They wanted inter alia to show that controversy on details may be endless and sterile, and even offuscate the vision of the

drama and the stage in which man's fortunes are played out. And they hope that many of the critics will turn their talents to the constructive task of exploring what we all -- the protagonists -- should do to play our part right.

Annex C

SOME HIGHLIGHTS OF THE GROWTH DEBATE

9 February 1972

Letter from Mr. Sicco Mansholt (at that time European Commissioner) to the Chairman of the Commission of the European Communities, making explicit reference "to the study performed by the Systems Dynamics Group of MIT". He declared that faced with such a problematique "the cause would be lost if Europe refused to take the initiative", as according to him "the United States do not have the necessary political force to guide the world towards a solution". He asks for birth control also in highly developed countries. As to economic aspects, he questions the possibility of implementing the necessary measures and maintaining the present structure of society; he excludes, however, state socialism as a possible solution. His main point is to demand that we do not "orient any more our economic system towards.... a maximization of the Gross National Product (GNP) but to replace the latter instead by the 'Gross National Utility' (GNU)". To this end he proposes a European General Economic Plan and a five-year plan for the development of a 'clean and recycling' (CR) production system. He suggests that the Commission implement a system of CR production certificates and corresponding fiscal and tax measures, promote the durability of consumption goods, create a European distribution system for raw materials, and orient research towards a 'utility' rather than a 'growth' goal.

This letter raises considerable controversy which reaches its culminating point in April 1972 on the occasion of the French referendum on the enlargement of the European Community, right-wing Gaullists and the French Communist Party being the most hostile to Mr Mansholt's theses.

(M. Debré: "The members of the Commission are not politically responsible"; G. Marchais: "A Europe of misery and economic repression"). Other political tendencies show in general careful, sometimes even warm approval of Mansholt's principles, the main reservations being those concerning his proposals for concrete action.

April 1972

Conference of the Commission of the European Communities in Venice on the theme 'Industry and Society', with Chairman Mansholt's theses in the centre of interest. Contrary to Mr. Mansholt, European Commissioners Barre and Spinelli prefer the line of the 'technological fix' in a traditional economy.

May 1972

The 'Rencontres Internationales' organized in Paris at the initiative of Valéry Giscard d'Estaing with the Club of Rome themes as the centre of the discussion, and the participation among others of Swedish Prime Minister Palme, President Senghor of Senegal, Chairman Mansholt and Vice-Chairman Barre of the Commission of the European Communities, Roger Garaudy, Professor Herman Kahn, John Kenneth Galbraith and Bertrand de Jouvenel). The need for a new kind of growth, a 'humanized growth', is generally endorsed.

May 1972

UNCTAD Conference in Santiago de Chile with questions of growth limitations, necessity of a global approach and equilibrium between developing and developed countries, on the agenda.

June 1972

UN Conference on the Human Environment in Stockholm. The third point of the Final Declaration reflects many of the ideas which led to the 'limits' research:

"Man has constantly to sum up experience and go on discovering, inventing, creating and advancing. In our time, man's capability to transform his surroundings, if used wisely, can bring to all peoples the benefits of development and the opportunity to enhance the quality of life. Wrongly or heedlessly applied, the same power can do incalculable harm to human beings and the human environment. We see around us growing evidence of man-made harm in many regions of the earth: dangerous levels of pollution in water, air, earth and living beings; major and undesirable disturbances to the ecological balance of the biosphere; destruction and depletion of irreplaceable resources; and gross deficiences harmful to the physical, mental and social health of man, in the man-made environment, particularly in the living and working environment".

July 1972

UNESCO meeting of experts on science policy selected by Governments of the European Member States, in Budapest. The Committee of Experts, recognizing that "the pattern of world needs and resources is such that national long-term planning can no longer be conceived of solely in terms of increased material prosperity, if only because this framework gives insufficient weighting to conditions which will critically affect the future quality of man's life", recommends, as a matter of urgency "to stimulate the study of socio-economic development phenomena in an expanded framework, linking these

phenomena with the study of all natural processes and equilibria relevant to man's existence and the quality of that existence".

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UNESCO-sponsored Symposium in Holland on 'Young Scientists and Contemporary Society', organized by the World Federation of Scientific Workers, marks a real rupture with the spirit of the 'old generation'. The fragmentary character of today's sciences, the absence of an opening towards world problems and the 'elitist' character of scientific institutions are criticized. The notion of 'soft technology' is created: labour-intensive, mentally satisfying, ecology-preserving techniques. The MIT study is somewhat criticized for not having dealt with the waste of armaments and for placing too much emphasis on resource limitations rather than stating that the real root of most ills is a crisis of civilization: a single deep-lying problem with many diverse symptoms. This coincides with the Club of Rome thinking.

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Mid-1972

US Department of Commerce commissions a special study in response to 'limits'. At that time Mr. Elliot Richardson, Secretary of the US Department of Health, Education and Welfare, had already declared: " 'The Limits to Growth' must be taken seriously even if only half of its assertions prove true".

September 1972

Critical report on 'limits' prepared by a task group of the World Bank. Its main critical arguments are dealt with in this paper. World Bank President Robert S. McNamara, declared in 1971, in a different context: "The marginal men, the wretched strugglers for survival on the fringes of farm and city, may already number more than half a billion. By 1981, they will surpass a billion; by 1990, 2 billion. Can we imagine any human order surviving with so gross a mass of misery piling up at its base?".

October 1972

Russell Train, Chairman of the US Council on Environmental Quality, explicitly endorses The Club of Rome approach as a guideline for the future.

"A question to which we must address ourselves is the limits of the carrying capacity of the earth itself. . . . . I suggest that . . . . we inquire into the ability of our institutions to cope with change, to get food and fiber products to where people are, and to protect us from some of our own breakthroughs when , for example, a green revolution proves vulnerable to insects, or enhanced agricultural productivity causes farmers to inundate the cities in search of work . . . . We must ask whether

the market allocates long-term needs in an effective manner of whether prices only rise when a resource is close to depletion. Instead of dismissing these matters with an ideological reflex, we must apply careful analysis, for it is by no means clear that the marketplace and technology will solve all of our problems in an even-handed manner . . . . Another issue we face is how to develop technology in such a way as to make use of its benefits while at the same time anticipating potentially harmful side effects and taking those actions which reduce the risk of developing technology. The problem is particularly severe in that the side effects are often second or third order, their anticipation difficult, and the development of adequate safeguards complex.

All of these questions suggest that we must improve our ability to understand the future. This means not only better projections of future trends, but a more profound understanding of the interrelationship among a wide variety of factors such as population, food, industrial growth, resources and pollution. . . . . Indeed, we must act as 'one World'.

<u>October 1972</u>

Press Conference by Giovanni Agnelli, Chairman of Fiat, at the Turin Motor Show:

". . . . Many of the conclusions of the MIT I find particularly stimulating even if reality is perhaps much more complex than the model introduced into the computer. At any rate, I hope that there will develop around them not only controversies but also studies and concrete projects to create tools for the control of the possibly negative effects of the most advanced technologies without thereby sacrifying the forces of economic and social development, which

is still needed by such a great part of the world in order to eliminate its oldest ills: hunger, ignorance and endemic diseases".

October 1972

The first 'Information Week' organized by the Japanese Government to launch the plan to transform Japanese society into a 'knowledge-information society'. This and many other attitudes in Japan with respect to the future are to a large extent inspired by The Club of Rome thinking.

November 1972

The Second Symposium on economic and legal questions of environmental protection (University of St. Gallen, Switzerland) deals with the problem of the direction and ends of economic growth, with 'limits' as the hub of the discussion. Well-renowned national-economists like Prof. Francesco Kneschaurek, who were thought to take the stand of traditional growthism, pleads for qualitative rather than quantitative growth and qualifies the ecological controversy as being "too often emotionally overcharged, ideologically biased and filled with clichés stemming partly from political opportunism, partly from simple hypocrisy". Even more critical towards the conventional concept of economic growth are Prof. Emil Küng and Prof. Josuah Werner.

November 1972

Quality of life and a new kind of growth, as opposed to the goals of a society of consumption ('growth fetishism') and to artificially stimulated material aims, are points to be found in the election program of the German Social Democratic Party.

November-December 1972

During the elections in the Netherlands, 'limits' and even 'zero growth' theses are among the major issues.

January-February 1973

US Congressional Hearings scheduled for three to four weeks in the House of Representatives on 'Growth and the American Future'.

February 1973

Meeting of the Ontario Research Foundation in Toronto, Canada, on aspects of the Predicament of Mankind.

March 1973

The American Association for Higher Education has selected as its principal theme for its annual convention the implications of 'The Limits to Growth' for planning in American Universities.

AND SO ON.......

A Summary of Limits to Growth - its Critics and its Challenge

Donella H. and Dennis L. Meadows

This discussion was originally presented at Yale University, September, 1972, in the School of Forestry's symposium on limits to growth. An extended version of the text appeared in Futures, February 1973.

Introduction

Over the past two years we have worked with a group of scientists and students to understand the long-term causes and consequences of growth in the globe's population and material output. From our research we have been led to conclude that current growth rates cannot be sustained even for the lifetimes of the children being born today. If society maintains its current reliance on growth to solve short-term problems, we believe that population and material production will grow past sustainable limits, that the carrying capacity of the earth will be eroded, and that there will then be an uncontrolled decline in population and economic activity. However, this outcome does not appear inevitable. Mankind could instead begin to assess realistically the limits to material growth. Society's goals and instituions could be altered to reduce growth now and to move ultimately towards an orderly accommodation with the finite constraints of the globe. If these changes were made, it would probably be possible to sustain the world's population more or less indefinitely and to provide for all its basic needs.

Our view of growth and its consequences were developed through the construction of World3, a mathematical model of the physical, biological, psychological, geological and other causes underlying growth. Many objections have been raised to our approach and results. In this presentation we would like to describe the history of our work, to summarize the basic foundations of our thesis, and to respond to the most common criticisms of our conclusions.

Historical Summary

With the publication of World Dynamics[1], Professor Jay W. Forrester challenged the world's scientists and decision makers to extend their time horizons and to examine in holistic fashion the long-term causes and consequences of growth in the world's population and material output. To contribute to analysis and understanding of global problems Forrester proposed a formal model of the interactions among population, capital, and several factors that influence their growth: food, resources, and pollution. Recognizing that his model was not perfect or complete, Forrester emphasized that no perfect or complete model exists, and that the models on which decisions are now based are not even explicit enough to be discussed and improved:

2. <u>There are physical limits to population and capital growth</u>. The World models are built upon the Malthusian assumption that the earth is finite, and that some change in current exponential growth processes will thus be necessary to accomodate man's physical presence and activities to the earth's limits. The purpose of the models is to investigate what kinds of changes might and should occur. We chose to investigate a Malthusian view of a limited world because our own impressions and much empirical data suggest that the world is finite in several important ways. It seems to us not only more realistic, but more socially responsible and more useful to investigate the ways in which society might adjust itself to earthly limitations, rather than to assume away all such limitations.

The World models express the idea of the earth's limits through four explicit assumptions: there is a finite stock of exploitable nonrenewable resources, there is a finite capacity for the environment to absorb pollutants, there is a finite amount of arable land, and there is a finite yield of food obtainable from each hectare of arable land. No one has exact information about where these limits are. In fact it is probably impossible to express any one of these limits by a single number since they all vary with time. We know that to a certain extent they are expandable by technology. We also know that they can be reduced by misuse.

By attempting to represent the world's limits and the growth of the physical system toward them we did not expect to gain any more precise information about the location or values of the limits themselves. We did try to achieve two other purposes. First, we sought a framework in which many growth processes and limits could be considered together, to illustrate that solutions proposed for any one problem related to growth are meaningless without considering the system as a whole. The traditional approach of specialists in any one area, for example, resource economics, food production, or environmental deterioration, amply illustrates how easily any single resource, food, pollution, or population problem can be mentally "solved" by assuming that sufficent capital, energy, labor, land, material and time can be allocated to that one problem. Because they are holistic, the World models force one to explore the possibility that several of these problems may have to be solved simultaneously. We are interested

in that possibility because our perception of exponential growth indicates to us that these problems will not come slowly, one at a time.

Our second concern was to represent not only the forces that can increase the earth's carrying capacity for human activity but also the forces that can reduce it. From our Malthusian point of view, Western man is entirely too prone to rejoice in his newly-irrigated land, underwater oil-drilling rigs, Green Revolutions, and catalytic converters and to ignore the eroded, salinized, or strip-mined land, the dumps of wasted resources, the depleted ore bodies, the simplified ecosystems, and the deprivation of other humans in other cultures that he leaves in the wake of his "progress". The World models contain assumptions of possibilities for considerable future progress, but they also take into account mankind's fallibility. They assume that the limits can be pushed downward, as well as upward, by man's activities.

There are, of course, other limits we have not included in the World models. The most obvious omissions are the limits to the sustainable rate of use of renewable resources - fresh water, timber, fish, and game for example. We also recognized the importance of social limits, but omitted them from specific analysis. We stated in Limits (pp. 45-46) that social limitations (unjust distribution, waste, wars) would only decrease the possibilities for growth allowed by physical limits.

3. There are long delays in the feedback processes that control the rate of physical growth in the world system. Delays are the main source of instability in the global system. When rapid growth is coupled with a long delay between cause and effect, the growth may proceed far beyond sustainable limits before the effects that can stop it come into play. We have not assumed that mankind is unresponsive to the changing situation around him. We have simply assumed that social institutions respond only to situations about which they have information, that the information they act on is often incomplete and late, and that the social response is not immediate but is itself delayed. The response delay can be caused by political, physical, or biological processes. It is increased by the time required to invent/construct/test/perfect new technologies. Many response delays are beyond control, such as the delays inherent in the population age structure or in the propagation of persistent materials through the environment.

The combination of three major assumptions causes the "overshoot mode" of the models: the assumption of feedback delays, the assumption of limits to the earth's carrying capacity, and the assumption that the human value system will promote population and material growth until counteracted by very strong forces. When, in the "equilibrium" mode, we assume a change in man's value system in favor of stability and against sustained population and capital growth, the overshoot no longer occurs. The overshoot could also be eliminated, or minimized, by assuming that the society can avoid the implications of delays by conducting accurate long-term planning. Of course our purpose in publishing Limits was to encourage both the value-change and the long-term planning processes.

4. There are two possible social responses to the limits to growth; weaken growth forces or remove the symptoms of impending limits. The common response of modern social systems to the pressure caused by limitation of any resource is to remove the pressure so that growth can continue. Highways are jammed; build more highways. Copper reserves are depleted; import copper. Electric power is insufficient; develop nuclear power plants. People are hungry; buy fertilizer.

It is only very recently and very weakly that an alternative set of solutions has been seriously proposed; reduce the use of automobiles, use less electric power, extend the useful lifetime of material goods, have fewer children. This second set of responses recognizes that the problem to be solved is not scarcity of a specific resource; highways, copper, power or food. These scarcities are symptoms, or signals, of the underlying problem; population and material growth against a finite resource base. The first set of responses serve to remove temporarily the adverse symptoms of growth. If they are not accompanied by responses of the second type, that weaken the social values causing growth, further growth will eventually cause different resource scarcities. These scarcities will call for additional technological solutions to remove the signals of impending resource limits. The real danger of responses of the first type, responses that ease the symptoms of the problem is that they are often used to discourage responses of the second type, those that control growth itself. The more successfully the signals of resource scarcity are masked and denied, the more likely it is that the necessary social value change will come too late.

As we stated in Limits, we have no desire to stop the development of technology. Combined with the necessary value changes that will control physical growth, carefully selected new technologies can create magnificient possibilities for human society. We are, however, concerned that technological successes have almost invariably been used to enhance, rather than reduce, the strengths of the positive population and capital feedback loops that drive the global system. We do not oppose technology. We do oppose the present trend of technological "progress" that is not only poorly guided by social wisdom or restraint, but is used as an excuse not to develop that wisdom or restraint.

5. The equilibrium state may be a desirable option, wherever the limits to growth may be. It is not necessary to agree with the World models or to believe in the imminence of any physical limits to growth to become intrigued by the nature and potential of an equilibrium state. An equilibrium state is a society that has stabilized its population at a desired level and that supplies its material needs with a minimum throughput of nonrenewable, pollution-creating resources. Limits ends with a rather Utopian description of such a state. We sincerely believe that some form of deliberate material and population equilibrium is attainable, not immediately,but within a generation or two. We also believe that the exercise of understanding and planning how such a state might work is both exciting and useful in that it might provide the realistic, sustainable, long-term goal that is now lacking in nearly every part of world society. It seems impossible to us that material growth can be successfully controlled unless there is some well-defined goal towards which it may be directed. There is no way of deliberately changing the composition of growth or its distribution unless there is a clear vision of what growth is for. The specifics of the goal will change and develop as more is learned about the world. We feel that it is only important to have such a goal and to keep it consistent with present knowledge.

The idea of a physically non-growing society is so foreign to some people that they have invested the idea with some strange mental models of their own. They have suggested that an economy at material equilibrium must be stagnant intellectually or technologically; that it must be rigid and dictatorial; that it must preserve the present maldistribution of resources or income. We have already suggested in Limits that we would expect just the reverse. We would hope that more imaginative respondents will accept the challenge of thinking

through the economics and sociology of a physically stabilized state.[5] We suspect that the exercise would be more than theoretical; that it would illuminate some of the current economic and sociological problems of a growing state as well.

We have not suggested in Limits or elsewhere that the equilibrium state should be attained immediately, or that physical growth should be brought to a sudden halt. On the contrary we have pointed out long delays in the social system and the necessarily gradual nature of demographic change, and we have suggested that an orderly shift to equilibrium from present rates of growth may take as long as 100 years. Thus although the first steps toward equilibrium should be small ones, they should be taken soon. A good beginning might be a common recognition that physical growth cannot be forever substituted for the social resolution of difficult choices.

In summary, we believe the basic points of our modeling effort, as described in Limits, merit consideration even though none of them can be supported by rigorous proof. No social model can be rigorously proved true. Together these points constitute a holistic hypothesis about the world system that is generally consistent with real-world observations. We do not believe that the same can be said for the mental models on which important decisions with long-term implications are currently based.

Price, Technology, and Values

Let us turn now to the three mechanisms that many critics of Limits believe will allow mankind to sustain and control material growth without any changes in the current system - price, technology, and social value change. All three are actually included in the World models, but in implicit and oversimplified form. Of course all three are important, complex, dynamic subsystems in themselves. We will describe here, very briefly, how more complete representations of these subsystems might be constructed. However, none of the added details would alter the basic conclusions of our work.

Economic price is a function of two socially determined variables---the current value society places on a certain good or service and the apparent cost of supplying that good or service. Economists postulate that the long-term stabilizing role of price in a growing system is to signal resource scarcity. They point out that price changes guide social values and

the economic system so that the declining supply of a scarce resource is utilized more efficiently.

When increasing scarcity causes the price of some material to rise, numerous social responses may be triggered. There may be a more intensive search for natural deposits of that material, or increased recycling of discarded products containing it. Food shortages leading to rising food prices may stimulate farmers to adopt more efficient methods of production, governments to irrigate more land or people to eat less food. These dynamic effects of the price mechanism will indeed influence the way in which a growing system approaches its physical limits.

World3 contains several causal relationships between the real supply of some economic quantity (such as food, nonrenewable resources, industrial capital, service capital) and the response of the economic system to scarcity of that supply (develop more agricultural land, allocate more capital to resource production, increase investment rates). These relationships are most realistically represented with price as an intermediate variable:

decease in supply ⟶ rise in price ⟶ social response

In World3 we have simplified the real dynamics of the price mechanism by eliminating explicit reference to price, the intermediate variable: The representation of the causal chain has been shortened to:

decrease in supply ⟶ social response

The ultimate regulating effect of the price system is thus included, but price does not explicitly appear in the model.

The only purpose of eclipsing the price mechanism in this way is to increase the model's simplicity and understandability. Omission of price is equivalent to assuming that the signals provided by the price system are available to social decision points with a delay that is insignificant on a 200-year time scale. To check the validity of this omission, several of our submodels explicitly included price and its effects on technological advance and resource availability. The general long-term behavior of these submodels was similar to that of the World model's resource sectors.

To the extent that prices do not immediately reflect actual resource costs in the real world, the price system will be a source of additional instability in the world system. Instability will also be increased if cost information is transmitted immediately but to institutions that can adjust their production or consumption patterns only after a long delay. In either case, the delay between decreased availability and social response will reduce the stability of the economic system as it adjusts itself to any limit. Thus by assuming in World3 that the price system works instantaneously we have omitted a source of system instability. To the extent that prices are actually delayed signals of scarcity, our model will underestimate the tendency of real economic systems to overshoot physical limits.

We view technology, like price, as a social phenomenon - it is the application of man's general knowledge about the world to the solution of a specific, perceived human problem. If we were to make a complete dynamic model of the development of a given technology, we would include the following:

- a level of accumulating general knowledge, with the rate of accumulation dependent on the resources devoted to basic research.
- a widespread perception of some human problem.
- an allocation of physical resources, human effort, and time to search for a technical solution to the problem, with a realization that the solution may not be found if the level of knowledge is not yet great enough.
- a delay to allow social acceptance and implementation of the new technology, the length of the delay dependent on the magnitude of the required departure from the present way of doing things.
- a representation of the total impact of the technology on the system, including social, energy, and environmental costs.

This model of technological advance might be contrasted with the one advanced in separate papers by Boyd, Cerlemans, and the Sussex group.[6,7,8] Each assumed that technology is inherently exponential and that the appropriate technical capabilities are instantaneously available whenever needed. They have supposed that technological advance costs nothing, requires no capital

investment, has no harmful side effects, and encounters no resistance from institutions already present. Not surprisingly, when their representations of technology were inserted in World2, the model grew far beyond the original point of collapse. We would suggest that their theories of technological advance are so completely foreign to anything available in the real world, that their revisions of World2 provide no useful information whatsoever about the real implications of physical growth in a finite world.

Nearly every causal relationship in the World models could conceivably be changed by some sort of new technology. In the past various technologies have, directly or indirectly, improved birth control effectiveness, increased land productivity, and increased the average generation of persistent pollution per unit of industrial output. The advance of technology has created more costly and destructive weapons, increased life expectancy through medical advance, and hastened the rate of land erosion. It is by no means certain that technologies will continue to do any of these things in the future, since the human values and social institutions that govern technological development are always subject to change.

In other words, we view technology as socially-determined, discontinuous, infinitely varied, and delayed. It is nevertheless an important determinant of the functioning of the world system. How can such a concept be included in a world model? Since so many causal relationships might be altered by some conceivable technological change, we had to consider building technological change into each relationship as we formulated it. We did this by assigning possible technologies to three categories; those that are already feasible and institutionalized, those that are feasible but not institutionalized, and those that are not yet feasible.

Some causal relationships have historically been altered by technology and continue to be altered regularly today. These are in areas where there is social agreement about the desirability of change, and where resources and institutions to bring about that change are already integral parts of the system. Examples are medical technology to improve health, industrial technology to raise production efficiency, agricultural technology to increase land yields, birth control technology to plan family size, and mining technology to discover and exploit lower-grade nonrenewable resources. A significant fraction of the world's people have adopted the value system that will continue to promote these

technologies as long as their costs can be afforded. They are effectively built into the world socio-economic system. Therefore, they are also built into the relationships of the World models, with the assumption that they will continue to develop and spread through the world, without delay, as long as there is economic support for them.

There are other technologies that have not been so widely accepted that they can be considered a functioning part of the world system. It is not yet clear that all the nations of the world are willing to institutionalize and pay for technologies such as pollution control, resource recycling, capture of solar energy, preservation of soil fertility, alternatives to the internal combustion engine, or increased durability of manufactured goods. All of these technologies are feasible, and there are signs of the social value changes necessary to incorporate them into the world system. It is not possible to know when or even whether they will be adopted on a worldwide scale. Therefore we have not assumed them in the model relationships, but we have included many of them as optional functions, which a model operator can "turn on" at any specified time in the future. The model can be used to test the possible impact of any or all of these technologies and the relative advantages of adopting them sooner rather than later.

There is a third set of technologies that is not included in the model at all. That is the set of discoveries we cannot possibly envision from our perspective in time. Of course no model, mental or formal, can incorporate these unimaginable technologies as they will actually occur. That is one reason why no model can accurately predict the future. Any long-term model that is being used to aid the policy making process must therefore be updated constantly to incorporate surprising discoveries as they occur, and to assess how they may change the options of human society.

It is possible, of course, to include in the model the assumption that some unimaginable discovery will come along in time to solve every human problem, including the limited resource base of the earth. Many mental models seem to be based on that assumption. However, our bias as both modelers and managers is to search for understanding and for better policies based on the constraints of the system as it appears now, not to rely on developments that may or may not come in the future.

We have already indicated that both technology and price are dynamic elements directly dependent upon the values, needs,and choices characteristic of the human society. Of course values underlie many of the other dynamic elements of interest in a model of physical growth. In fact the whole socio-economic system might be thought of as a constant interplay of human desires and goals within physical and biological constraints. Therefore, although the World models are not intended to be models of social value change, they must contain some assumptions about the dynamics of human values insofar as they influence and are influenced by the processes of physical growth.

In the difficult task of modeling human values we have tried to include only those most basic values that can be considered globally common. These basic values begin with requirements for survival, such as food, and go on to include a hierarchy of other desires; for longevity, children, material goods, and social services such as education. Some of these values are represented explicitly in the model as variables that have an important influence on economic decisions. Examples from World3 are desired completed family size, and preferences among food, material goods, and services at different income levels. Others are included implicitly, for example in the allocation of service output to health services or in the quantity of nonrenewable resources used per capita.

All of the values included in World3 are assumed to be responsive to the actual physical and economic condition of the system; they are all involved in feedback loops. The patterns of dynamic value change included in the model, however, are limited to the patterns of change historically observed in individual countries over the last hundred years or so. During that time the major force behind value change in the world sytem has been the process of industrialization, a process that is still underway in most of the nations of the world. Therefore the values that both shape and respond to the development of the model system follow the historic pattern of industrialization. As industrialization increases in our model (measured, say, by the level of industrial capital per capita) the aggregate social demand in our model shifts in emphasis from food to material goods and finally to services. Other changes occur in the model in the preferences for children, education, and health care, and in the distribution of various goods and services throughout the industrializing population.

We have not built into World3 any global shifts in values other than those that might be expected to take place as the world becomes more industrialized. Again, the model cannot predict value changes, but it can serve as a test device to show the results of any given assumption about the future evolution of values, Human values, like human technologies, may evolve in the future in directions we cannot possibly foresee at this moment in history. Therefore we have also included, in several model relationships, test switches that can be used to activate postulated value changes at any date specified by the operator. (Examples of such changeable values are desired family size, fraction of output consumed, and the relative desires for food and services. All of these are changed to produce the model's "equilibrium" runs.) We have used these switches extensively. As we demonstrated in Limits, an appropriate set of value changes can bring the model system into a stable and desirable equilibrium state. That set of value changes is not one that has occurred historically as a result of industrialization in any country. We believe that such value changes are possible to achieve in the future, but only by a concerted and conscious effort. The shift in values that normally accompanies industrialization, the one we might expect to take place if the world continues "business as usual", is the very value shift that leads to the overshoot and decline behavior mode.

The Modeler and his Environment

It has been suggested that the World models arose only because of the sudden widespread concern about the environment in modern western societies. Of course computer models, like any product of man's intellect, must be evaluated as part of the cultural context within which they are constructed. This statement is also true for the mental models of the critics of Limits and for the models that guide current public policy.

Every model of a social system must omit some details of the real world. Simplification is the essence of model building. A model is constructed to improve understanding of the nature and implications of complex relationships in the real world. If the model were identical to the real world in all respects, it would be as difficult as the real world to understand.

> It is a very fundamental principle indeed that knowledge is always gained by the orderly loss of information, that is by condensing and abstracting and indexing the great buzzing confusion of information that comes from the world around us into a form which we can appreciate and comprehend.[9]

Thus even if we had comprehensive and accurate information on all important aspects of the real world, our models would be simplifications of reality.

Human judgment is inextricably involved in the choice of the issues addressed by a model and in the identification of those "unimportant" details that may be eliminated without detracting significantly from the explanatory power of the model. Every model is thus inevitably influenced by prevailing social values and goals. In short, there is no model useful for understanding all issues and no "scientific" or "objective" way to construct a perfect model.

The greatest advantage of formal, or written, models over mental models is that their constituent assumptions are precise and explicit and thus subject to the scrutiny of critics. This is no guarantee against error or against the effects of unwarranted social biases, but it makes the discovery of errors and biases more likely. Most critics of Limits have not defined the bias that underlies their own approach, nor have they presented assumptions explicit enough to be judged by their audience.

The accusation that the World models have been unduly influenced by the prevailing environmental concern seems to imply that the models are addressing random, unimportant, or spurious issues. The latest wave of environmentalism may indeed turn out to be a fad, merely the product of rising expectation, or boredom, or alarmist journalists, or all of these. However, there is an alternate possibility. The current concern with the environment may be a response to a correct perception of a changed external reality. It may be a result of the first glimmerings of human understanding about total systems and the first perception of a real worldwide negative impact of man's activities on the ecosystem. If so, the World models may represent a small manifestation of a healthy social reaction to an environmental change; a reaction that will lead to new values, technologies, and economic prices that attempt to adapt socioeconomic systems to the newly-perceived constraints. In that case the critics, the technological optimists, the foot-draggers who claim that there

are no constraints and no reasons to change values from the present pro-growth set, represent exactly the social and institutional delays that tend to destabilize the system and send it shooting past its ultimately sustainable limits.

Growth and Income Distribution

Some critics have rejected the no-physical-growth argument as irrelevant to the "really important" problems of the composition and distribution of growth. As we have already indicated, we find it impossible to view the rate of physical growth, its composition and its distribution as independent or mutually exclusive problems. Human societies will not achieve a more equitable distribution of wealth until they better understand the processes of growth. Historically at least, growth of population and of capital has been correlated with the concentration of wealth and with rising gaps between the absolute incomes of the rich and the poor. We believe that there are at least two basic reasons for these trends. First, physical growth inevitably worsens the resource/population balance. When there are fewer available resources per person, there are also fewer real social options to resolve conflicts of interest. Second, by relying on the false promise of growth, social institutions are able to delay facing the very important and difficult tasks of making social tradeoffs and defining social goals. Until these tasks are squarely faced there will be no real redistribution of income.

The no-growth argument is an appeal for readjusting the composition and distribution of economic output. The pro-growth argument is an attempt to postpone this readjustment; to confer it on future generations. Simultaneously this approach ensures that those generations will have fewer resources and thus fewer real choices to make. Our sociopolitical concerns are actually quite similar to those who argue that redistribution must come first. We differ only in our perception of how to deal with those concerns. Our own choice was to begin by questioning what we view as the basic cause of the growing gap between the rich and the poor - unexamined, uncontrolled physical growth.

V. The Concept of Man

This brings us to the final point that we regard as basic to all discussions among ecologists, "environmentalists", Malthusians, economists, industrialists, pessimists, and optimists. The pro- and anti-growth factions are organized around two very different concepts of man.

One concept of man, the one held by advocates of indefinite growth, is that Homo sapiens is a very special creature whose unique brain gives him not only the capability but the right to exploit for his own short-term purposes all other creatures and all resources the world has to offer. This is an age-old concept of man, one firmly rooted in Judeo-Christian tradition and newly strengthened by stunning technical achievements in the last few centuries.

> Not only ingenuity but, increasingly, understanding; not luck but systematic investigation, are turning the tables on nature, making her subservient to man.[10]

According to this belief man is essentially omnipotent, he can develop at no cost a technology or a social change to overcome any obstacle, and such developments will occur instantly upon the perception of the obstacle. Underlying this view is also the belief that mankind's social, economic, political, and technical institutions operate flexibly and without error, and the best response to any apparent problem is to encourage these institutions to do more of whatever they have done in the past.

The opposite concept of man is also an ancient one, but it is more closely related to the Eastern religions than to the Western ones. It assumes that man is one species with all other species embedded in the intricate web of natural processes that sustains and constrains all forms of life. It acknowledges that man is one of the more successful species, in terms of competitiveness, but that his very success is leading him to destroy and simplify the natural sustaining web, about which he understands very little. Subscribers to this view feel that human institutions are ponderous and short-sighted, adaptive only after very long delays, and likely to attack complex issues with simplistic and self-centered solutions. They would also point out that much of human technology and "progress" has been attained only at the expense of natural beauty, human dignity, and social integrity, and that those who have suffered the greatest loss of these amenities have also had the least benefit from the economic "progress". People who share this concept of man, as we do, would also question strongly whether technology and material growth, which seem to have caused many problems, should be looked to as the sources of solution of these same problems in the future. Technological optimists invariably label this view of the fallibility of man as "pessimistic"; Malthusians would simply call it "humble".

We see no objective way of resolving these very different views of man and his role in the world. It seems to be possible for either side to look at the same world and find support for its view. Technological optimists see only rising life expectancies, more comfortable lives, the advance of human knowledge, and improved wheat strains. Malthusians see only rising populations, destruction of the land, extinct species, urban deterioration, and increasing gaps between the rich and the poor. They would say that Malthus was correct both in his own time and today in his observation that:

> ...the pressure arising from the difficulty of procuring subsistence is not to be considered as a remote one which will be felt only when the earth refuses to produce any more, but as one which actually exists at present over the greatest part of the globe.[11]

The Challenge

One glaring problem confronts mankind, if it should choose to conceive of man as a humble part of the biosphere. There is essentially no body of knowledge from which to design the new institutions, and values consistent with that concept of man. Two hundred years of growth has left biases and blind spots throughout the physical and social sciences. There is today no economic theory of a technological-based society in which there are essentially zero interest rates, no net accumulation to society's productive capital, and in which the principal concern is equality rather than growth. There is no equilibrium sociology which is concerned with the social aspects of a stable population, whose age composition is skewed toward the elderly. There is no equilibrium political science in which we might look for clues to the ways democratic choice could be exercised when short-term material gain is ruled out as the basis for political success. There is no equilibrium technology that places high emphasis on the recycling of all matter, on the use of the sun's pollution-free energy, and on the minimization of both matter and energy flows. There is no psychology for the steady state which might provide man with a new self-image and with feasible aspirations in a system where material output is constant and in balance with the globe's finite limits.

Each of our traditional disciplines could respond to the challenge of working out the details of a viable and attractive equilibrium society. The effort would pose many difficult technical and conceptual problems, whose

solutions would be intellectually satisfying and of enormous social value. After all, we are not merely talking of a distant and unattainable Utopian state. Physical growth of population and capital will stop on this finite planet. The only uncertainties lie in when it will stop and how - by deliberate social choice and under careful human management, or by the harsh backlash of a disturbed and depleted natural environment.

We may all find that the study of a steady-state society may be the best possible preparation for the real future - a future that we are shaping already, with every social and individual decision we make. We will almost certainly discover as we become better acquainted with the possibilities for an equilibrium society that we would prefer the end of physical growth to occur under our own management and sooner, rather than later. Those of us who have already spent several years adjusting to the idea of a no-material-growth society find without exception that we agree with John Stuart Mill, who contemplated the limits to growth more than one-hundred years ago:

> I cannot, therefore, regard the stationary state of capital and wealth with the unaffected aversion so generally manifested towards it by political economists of the old school. I am inclined to believe that it would be, on the whole, a very considerable improvement on our present condition. I confess I am not charmed with the idea of life held out by those who think that the normal state of human beings is that of struggling to get on; that the trampling, crushing, elbowing, and treading on each other's heels, which form the existing type of social life, are the most desirable lot of humankind.... It is scarcely necessary to remark that a stationary condition of capital and population implies no stationary state of human improvement. There would be as much scope as ever for all kinds of mental culture, and moral and social progress; as much room for improving the Art of Living and much more likelihood of its being improved.[12]

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A BLUEPRINT FOR SURVIVAL

Statement of Support

The undersigned, without endorsing every detail, fully support the basic principles embodied in the *Blueprint for Survival* which follows (pp 1-22), both in respect of the analysis of the problems we face today, and the solutions proposed.

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A BLUEPRINT FOR SURVIVAL

Preface

This document has been drawn up by a small team of people, all of whom, in different capacities, are professionally involved in the study of global environmental problems.

Four considerations have prompted us to do this:

1. An examination of the relevant information available has impressed upon us the extreme gravity of the global situation today. For, if current trends are allowed to persist, the breakdown of society and the irreversible disruption of the life-support systems on this planet, possibly by the end of the century, certainly within the lifetimes of our children, are inevitable.

2. Governments, and ours is no exception, are either refusing to face the relevant facts, or are briefing their scientists in such a way that their seriousness is played down. Whatever the reasons, no corrective measures of any consequence are being undertaken.

3. This situation has already prompted the formation of the Club of Rome, a group of scientists and industrialists from many countries, which is currently trying to persuade governments, industrial leaders and trade unions throughout the world to face these facts and to take appropriate action while there is yet time. It must now give rise to a national movement to act at a national level, and if need be to assume political status and contest the next general election. It is hoped that such an example will be emulated in other countries, thereby giving rise to an international movement, complementing the invaluable work being done by the Club of Rome.

4. Such a movement cannot hope to succeed unless it has previously formulated a new philosophy of life, whose goals can be achieved without destroying the environment, and a precise and comprehensive programme for bringing about the sort of society in which it can be implemented.

This we have tried to do, and our *Blueprint for Survival* **heralds the formation of the** MOVEMENT FOR SURVIVAL (see p 23) **and, it is hoped, the dawn of a new age in which Man will learn to live with the rest of Nature rather than against it.**

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A BLUEPRINT FOR SURVIVAL

Introduction: the need for change

110. The principal defect of the industrial way of life with its ethos of expansion is that it is not sustainable. Its termination within the lifetime of someone born today is inevitable—unless it continues to be sustained for a while longer by an entrenched minority at the cost of imposing great suffering on the rest of mankind. We can be certain, however, that sooner or later it will end (only the precise time and circumstances are in doubt), and that it will do so in one of two ways: either against our will, in a succession of famines, epidemics, social crises and wars; or because we want it to—because we wish to create a society which will not impose hardship and cruelty upon our children—in a succession of thoughtful, humane and measured changes. We believe that a growing number of people are aware of this choice, and are more interested in our proposals for creating a sustainable society than in yet another recitation of the reasons why this should be done. We will therefore consider these reasons only briefly, reserving a fuller analysis for the four appendices which follow the *Blueprint* proper.

111. Radical change is both necessary and inevitable because the present increases in human numbers and *per capita* consumption, by disrupting ecosystems and depleting resources, are undermining the very foundations of survival. At present the world population of 3,600 million is increasing by 2 per cent per year (72 million), but this overall figure conceals crucially important differences between countries. The industrialised countries with one-third of the world population have annual growth rates of between 0.5 and 1.0 per cent; the undeveloped countries on the other hand, with two-thirds of the world population, have annual growth rates of between 2 and 3 per cent, and from 40 to 45 per cent of their populations is under 15. It is commonly overlooked that in countries with an unbalanced age structure of this kind the population will continue to increase for many years even after fertility has fallen to the replacement level. As the Population Council has pointed out: "If replacement is achieved in the developed world by 2000 and in the developing world by 2040, then the world's population will stabilise at nearly 15.5 billion (15,500 million) about a century hence, or well over four times the present size".

112. The *per capita* use of energy and raw materials also shows a sharp division between the developed and the undeveloped parts of the world. Both are increasing their use of these commodities, but consumption in the developed countries is so much higher that, even with their smaller share of the population, their consumption may well represent over 80 per cent of the world total. For the same reason, similar percentage increases are far more significant in the developed countries; to take one example, between 1957 and 1967 *per capita* steel consumption rose by 12 per cent in the US and by 41 per cent in India, but the actual increases (in kg per year) were from 568 to 634 and from 9.2 to 13 respectively. Nor is there any sign that an eventual end to economic growth is envisaged, and indeed industrial economies appear to break down if growth ceases or even slows, however high the absolute level of consumption. Even the US still aims at an annual growth of GNP of 4 per cent or more. Within this overall figure much higher growth rates occur for the use of particular resources, such as oil.

113. The combination of human numbers and *per capita* consumption has a considerable impact on the environment, in terms of both the resources we take from it and the pollutants we impose on it. A distinguished group of scientists, who came together for a "Study of Critical Environmental Problems" (SCEP) under the auspices of the Massachusetts Institute of Technology, state in their report the clear need for a means of measuring this impact, and have coined the term "ecological demand", which they define as "a summation of all man's demands on the environment, such as the extraction of resources and the return of wastes". Gross Domestic Product (GDP), which is population multiplied by material standard of living appears to provide the most convenient measure of ecological demand, and according to the UN *Statistical Yearbook* this is increasing annually by 5 to 6 per cent, or doubling every 13.5 years. If this trend should continue, then in the time taken for world population to double (which is

estimated to be by just after the year 2000), total ecological demand will have increased by a factor of six. SCEP estimate that "such demand-producing activities as agriculture, mining and industry have global annual rates of increase of 3.5 per cent and 7 per cent respectively. An integrated rate of increase is estimated to be between 5 and 6 per cent per year, in comparison with an annual rate of population increase of only 2 per cent".

114. It should go without saying that the world cannot accommodate this continued increase in ecological demand. *Indefinite* growth of whatever type cannot be sustained by *finite* resources. This is the nub of the environmental predicament. It is still less possible to maintain indefinite *exponential* growth —and unfortunately the growth of ecological demand is proceeding exponentially (i.e. it is increasing geometrically, by compound interest).

115. The implications of exponential growth are not generally appreciated and are well worth considering. As Professor Forrester explains it,[1] "... pure exponential growth possesses the characteristic of behaving according to a 'doubling time'. Each fixed time interval shows a doubling of the relevant system variable. Exponential growth is treacherous and misleading. A system variable can continue through many doubling intervals without seeming to reach significant size. But then in one or two more doubling periods, still following the same law of exponential growth, it suddenly seems to become overwhelming".

116. Thus, supposing world petroleum reserves stood at 2,100 billion barrels, and supposing our rate of consumption was increasing by 6.9 per cent per year, then as can be seen from Figure 1, demand will exceed supply by the end of the century. What is significant, however, is not the speed at which such vast reserves can be depleted, but that as late as 1975 there will appear to be reserves fully ample enough to last for considerably longer. Such a situation can easily lull one into a false sense of security and the belief that a given growth rate can be sustained, if not indefinitely, at least for a good deal longer than is actually the case.* The same basic logic applies to the availability of any resource including land, and it is largely because of this particular dynamic of exponential growth that the environmental predicament has come upon us so suddenly, and why its solution requires urgent and radical measures, many of which run counter to values which, in our industrial society we have been taught to regard as fundamental.

117. If we allow the present growth rate to persist, total ecological demand will increase by a factor of 32 over the next 66 years—and there can be no serious person today willing to concede the possibility, or indeed the desirability, of our accommodating the pressures arising from such growth. For this can be done only at the cost of disrupting ecosystems and exhausting resources, which must lead to the failure of food supplies and the collapse of society. It is worth briefly considering each in turn.

Disruption of ecosystems

120. We depend for our survival on the predictability of ecological processes. If they were at all arbitrary, we would not know when to reap or sow, and we would be at the mercy of environmental whim. We could learn nothing about the rest of nature, advance no hypotheses, suggest no "laws". Fortunately, ecological processes *are* predictable, and although theirs is a relatively young discipline, ecologists have been able to formulate a number of important "laws", one of which in particular relates to environmental predictability: namely, that all ecosystems tend towards stability, and further that the more diverse and complex the ecosystem the more stable it is; that is, the more species there are, and the more they interrelate, the more stable is their environment. By stability is meant the ability to return to the original position after any change, instead of being forced into a totally different pattern—and hence predictability.

121. Unfortunately, we behave as if we knew nothing of the environment and had no conception of its predictability, treating it instead with scant and brutal regard as if it were an idiosyncratic and extremely stupid slave. We seem never to have reflected on the fact that a tropical rain forest supports innumerable insect species and yet is never devastated by them; that its rampant luxuriance is not contingent on our overflying it once a month and bombarding it with insecticides, herbicides, fungicides, and what-have-you. And yet we tremble over our wheatfields and cabbage patches with a desperate battery of synthetic chemicals, in an absurd attempt to impede the operation of the immutable "law" we have just mentioned—that all ecosystems tend towards stability, therefore diversity and complexity, therefore a growing number of different plant and animal species until a climax or optimal condition is achieved. If we were clever, we would recognise that successful long-term agriculture demands the achievement of an artificial climax, an imitation of the pre-existing ecosystem, so that the level of unwanted species could be controlled by those that did no harm to the crop-plants.

122. Instead we have put our money on pesticides, which although they have been effective, have been so only to a limited and now diminishing extent: according to SCEP, the 34 per cent increase in world food production from 1951 to 1966 required increased investments in nitrogenous fertilisers of 146 per cent and in pesticides of 300 per cent. At the same time they have created a number of serious problems, notably resistance—some 250 pest species are resistant to one group of pesticides or another, while many others require increased applications to keep their populations within manageable proportions—and the promotion of formerly innocuous species to pest proportions, because the predators that formerly kept them down have been destroyed. The spread of DDT and other organochlorines in the environment has resulted in alarming population declines among woodcock, grebes, various birds of prey and seabirds, and in a number of fish species, principally the sea trout. SCEP comments: "the oceans are an ultimate accumulation site of DDT and its residues. As much as 25 per cent of the DDT compounds produced to date may have been transferred to the sea. The amount in the marine biota is estimated to be in the

* It is perhaps worth bearing in mind that the actual rate of petroleum consumption *is* increasing by 6.9 per cent per year, and according to the optimistic estimate of W. P. Ryman, Deputy Exploration Manager of the Standard Oil Company of New Jersey, world petroleum reserves (including deposits yet to be discovered) are about 2,100 billion barrels.

order of less than 0.1 per cent of total production and has already produced a demonstrable impact upon the marine environment . . . The decline in productivity of marine food fish and the accumulation of levels of DDT in their tissues which are unacceptable to man can only be accelerated by DDT's continued release to the environment . . ."

123. There are half a million man-made chemicals in use today, yet we cannot predict the behaviour or properties of the greater part of them (either singly or in combination) once they are released into the environment. We know, however, that the combined effects of pollution and habitat destruction menace the survival of no less than 280 mammal, 350 bird, and 20,000 plant species. To those who regret these losses but greet them with the comment that the survival of *Homo sapiens* is surely more important than that of an eagle or a primrose, we repeat that *Homo sapiens* himself depends on the continued resilience of those ecological networks of which eagles and primroses are integral parts. We do not need to utterly destroy the ecosphere to bring catastrophe upon ourselves: all we have to do is to carry on as we are, clearing forests, "reclaiming" wetlands, and imposing sufficient quantities of pesticides, radioactive materials, plastics, sewage, and industrial wastes upon our air, water and land systems to make them inhospitable to the species on which their continued stability and integrity depend. Industrial man in the world today is like a bull in a china shop, with the single difference that a bull with half the information about the properties of china as we have about those of ecosystems would probably try and adapt its behaviour to its environment rather than the reverse. By contrast, *Homo sapiens industrialis* is determined that the china shop should adapt to him, and has therefore set himself the goal of reducing it to rubble in the shortest possible time.

Failure of food supplies

130. Increases in food production in the undeveloped world have barely kept abreast of population growth. Such increases as there have been are due not to higher productivity but to the opening up of new land for cultivation. Unfortunately this will not be possible for much longer: all the good land in the world is now being farmed, and according to the FAO[2], at present rates of expansion none of the marginal land that is left will be unfarmed by 1985—indeed some of the land now under cultivation has been so exhausted that it will have to be returned to permanent pasture.

131. For this reason, FAO's programme to feed the world depends on a programme of intensification, at the heart of which are the new high-yield varieties of wheat and rice. These are highly responsive to inorganic fertilisers and quick-maturing, so that up to ten times present yields can be obtained from them. Unfortunately, they are highly vulnerable to disease, and therefore require increased protection by pesticides, and of course they demand massive inputs of fertilisers (up to 27 times present ones). Not only will these disrupt local ecosystems, thereby jeopardising long-term productivity, but they force hard-pressed undeveloped nations to rely on the agro-chemical industries of the developed world.

132. Whatever their virtues and faults, the new genetic hybrids are not intended to solve the world food problem, but only to give us time to devise more permanent and realistic solutions. It is our view, however, that these hybrids are not the best means of doing this, since their use is likely to bring about a reduction in overall diversity, when the clear need is to develop an agriculture diverse enough to have long-term potential. We must beware of those "experts" who appear to advocate the transformation of the ecosphere into nothing more than a food-factory for man. The concept of a world consisting solely of man and a few favoured food plants is so ludicrously impracticable as to be seriously contemplated only by those who find solace in their own wilful ignorance of the real world of biological diversity.

133. We in Britain must bear in mind that we depend on imports for half our food, and that we are unlikely to improve on this situation. The 150,000 acres which are lost from agriculture each year are about 70 per cent more productive than the average for all enclosed land[3], while we are already beginning to experience diminishing returns from the use of inorganic fertilisers. In the period 1964–9, applications of phosphates have gone up by 2 per cent, potash by 7 per cent, and nitrogen by 40 per cent[4], yet yields per acre of wheat, barley, lucerne and temporary grass have levelled off and are beginning to decline, while that of permanent grass has risen only slightly and may be levelling off[5]. As *per capita* food availability declines throughout the rest of the world, and it appears inevitable it will, we will find it progressively more difficult and expensive to meet our food requirements from abroad. The prospect of severe food shortages within the next thirty years is not so much a fantasy as that of the continued abundance promised us by so many of our politicians.

Exhaustion of resources

140. As we have seen, continued exponential growth of consumption of materials and energy is impossible. Present reserves of all but a few metals will be exhausted within 50 years, if consumption rates continue to grow as they are (see Figure 2). Obviously there will be new discoveries and advances in mining technology, but these are likely to provide us with only a limited stay of execution. Synthetics and substitutes are likely to be of little help, since they must be made from materials which themselves are in short supply; while the hoped-for availability of unlimited energy would not be the answer, since the problem is the ratio of useful metal to waste matter (which would have to be disposed of without disrupting ecosystems), not the need for cheap power. Indeed, the availability of unlimited power holds more of a threat than a promise, since energy use is inevitably polluting, and in addition we would ultimately have to face the problem of disposing of an intractable amount of waste heat.

Collapse of society

150. The developed nations consume such disproportionate amounts of protein, raw materials and fuels that unless they considerably reduce their consumption there is no hope of the undeveloped nations markedly improving their standards of living. This vast differential is a cause of much and growing discontent, made worse by our attempts at cultural uniformity on behalf of an expanding market economy. In the end, we are altering people's aspirations without providing the means for them to be satisfied. In the rush to industri-

alise we break up communities, so that the controls which formerly regulated behaviour are destroyed before alternatives can be provided. Urban drift is one result of this process, with a consequent rise in anti-social practices, crime, delinquency, and so on, which are so costly for society in terms both of money and of well-being.

151. At the same time, we are sowing the seeds of massive unemployment by increasing the ratio of capital to labour so that the provision of each job becomes ever more expensive. In a world of fast diminishing resources, we shall quickly come to the point when very great numbers of people will be thrown out of work, when the material compensations of urban life are either no longer available or prohibitively expensive, and consequently when whole sections of society will find good cause to express their considerable discontent in ways likely to be anything but pleasant for their fellows.

152. It is worth bearing in mind that the barriers between us and epidemics are not so strong as is commonly supposed. Not only is it increasingly difficult to control the vectors of disease, but it is more than probable that urban populations are being insidiously weakened by overall pollution levels, even when they are not high enough to be incriminated in any one illness. At the same time international mobility speeds the spread of disease. With this background, and at a time of widespread public demoralisation, the collapse of vital social services such as power and sanitation, could easily provoke a series of epidemics—and we cannot say with confidence that we would be able to cope with them.

153. At times of great distress and social chaos, it is more than probable that governments will fall into the hands of reckless and unscrupulous elements, who will not hesitate to threaten neighbouring governments with attack, if they feel that they can wrest from them a larger share of the world's vanishing resources. Since a growing number of countries (an estimated 36 by 1980) will have nuclear power stations, and therefore sources of plutonium for nuclear warheads, the likelihood of a whole series of local (if not global) nuclear engagements is greatly increased.

Conclusion

160. A fuller discussion of ecosytems and their disruption, of social systems and their disruption, of population and food supply, and of resources and their depletion, can be found in Appendices A, B, C and D, respectively. There will be those who regard these accounts of the consequences of trying to accommodate present growth rates as fanciful. But the imaginative leap from the available scientific information to such predictions is negligible, compared with that required for those alternative predictions, laughably considered "optimistic", of a world of 10,000 to 15,000 million people, all with the same material standard of living as the US, on a concrete replica of this planet, the only moving parts being their machines and possibly themselves. Faced with inevitable change, we have to make decisions, and we must make these decisions *soberly* in the light of the best information, and not as if we were caricatures of the archetypal mad scientist.

161. By now it should be clear that the main problems of the environment do not arise from temporary and accidental malfunctions of existing economic and social systems. On the contrary, they are the warning signs of a profound incompatibility between deeply rooted beliefs in continuous growth and the dawning recognition of the earth as a space ship, limited in its resources and vulnerable to thoughtless mishandling. The nature of our response to these symptoms is crucial. If we refuse to recognise the cause of our trouble the result can only be increasing disillusion and growing strain upon the fragile institutions that maintain external peace and internal social cohesion. If, on the other hand, we can respond to this unprecedented challenge with informed and constructive action the rewards will be as great as the penalties for failure.

162. We are sufficiently aware of "political reality" to appreciate that many of the proposals we will make in the next chapter will be considered impracticable. However, we believe that if a strategy for survival is to have any chance of success, the solutions must be formulated in the light of the problems and not from a timorous and superficial understanding of what may or may not be immediately feasible. If we plan remedial action with our eyes on political rather than ecological reality, then very reasonably, very practicably, and very surely, we will muddle our way to extinction.

163. A measure of political reality is that government has yet to acknowledge the impending crisis. This is to some extent because it has given itself no machinery for looking at energy, resources, food, environmental disruption and social disruption as a whole, as part of a general, global pattern, preferring instead to deal with its many aspects as if they were self-contained analytical units. Lord Rothschild's Central Policy Review Staff in the Cabinet Office, which is the only body in government which might remedy the situation, appears not to think it worthwhile: at the moment at least, they are undertaking "no specific studies on the environment that would require an environmentalist or ecologist". There is a strong element of positive feedback here, in that there can be no appreciation of our predicament unless we view it in totality, and yet government can see no cause to do so unless it can be shown that such a predicament exists.

164. Possibly because government sees the world in fragments and not as a totality, it is difficult to detect in its actions or words any coherent general policy, although both major political parties appear to be mesmerised by two dominating notions: that economic expansion is essential for survival and is the best possible index of progress and well-being; and that unless solutions can be devised that do not threaten this notion, then the problems should not be regarded as existing. Unfortunately, government has an increasingly powerful incentive for continued expansion in the tendency for economic growth to create the need for more economic growth. This it does in six ways:

Firstly, the introduction of technological devices, i.e. the growth of the technosphere, can only occur to the detriment of the ecosphere, which means that it leads to the destruction of natural controls which must then be replaced by further technological ones. It is in this way that pesticides and artificial fertilisers create the need for yet more pesticides and artificial fertilisers.

Secondly, for various reasons, industrial growth, particularly in its earlier

phases, promotes population growth. Even in its later phases, this can still occur at a high rate (0.5 per cent in the UK). Jobs must constantly be created for the additional people—not just any job, but those that are judged acceptable in terms of current values. This basically means that the capital outlay per person employed must be maintained, otherwise the level of "productivity" per man will fall, which is a determinant of both the "viability" of economic enterprise and of the "standard of living".

Thirdly, no government can hope to survive widespread and protracted unemployment, and without changing the basis of our industrial society, the only way government can prevent it is by stimulating economic growth.

Fourthly, business enterprises, whether state-owned or privately owned, tend to become self-perpetuating, which means that they require surpluses for further investment. This favours continued growth.

Fifthly, the success of a government and its ability to obtain support is to a large extent assessed in terms of its ability to increase the "standard of living" as measured by *per capita* gross national product (GNP).

Finally, confidence in the economy, which is basically a function of its ability to grow, must be maintained to ensure a healthy state of the stock market. Were confidence to fall, stock values would crash, drastically reducing the availability of capital for investment and hence further growth, which would lead to further unemployment. This would result in a further fall in stock-market values and hence give rise to a positive-feedback chain-reaction, which under the existing order might well lead to social collapse.

For all these reasons, we can expect our government (whether Conservative or Labour) to encourage further increases in GNP regardless of the consequences, which in any case tame "experts" can be found to play down. It will curb growth only when public opinion demands such a move, in which case it will be politically expedient, and when a method is found for doing so without creating unemployment or excessive pressure on capital. We believe this is possible only within the framework of a fully integrated plan.

165. The emphasis must be on integration. If we develop relatively clean technologies but do not end economic growths then sooner or later we will find ourselves with as great a pollution problem as before but without the means of tackling it. If we stabilise our economies and husband our non-renewable resources without stabilising our populations we will find we are no longer able to feed ourselves. As Forrester[1] and Meadows[6] convincingly make clear, daunting though an integrated programme may be, a piecemeal approach will cause more problems than it solves.

166. Our task is to create a society which is sustainable and which will give the fullest possible satisfaction to its members. Such a society by definition would depend not on expansion but on stability. This does not mean to say that it would be stagnant—indeed it could well afford more variety than does the state of uniformity at present being imposed by the pursuit of technological efficiency. We believe that the stable society, the achievement of which we shall discuss in the next chapter, as well as removing the sword of Damocles which hangs over the heads of future generations, is much more likely than the present one to bring the peace and fulfilment which hitherto have been regarded, sadly, as utopian.

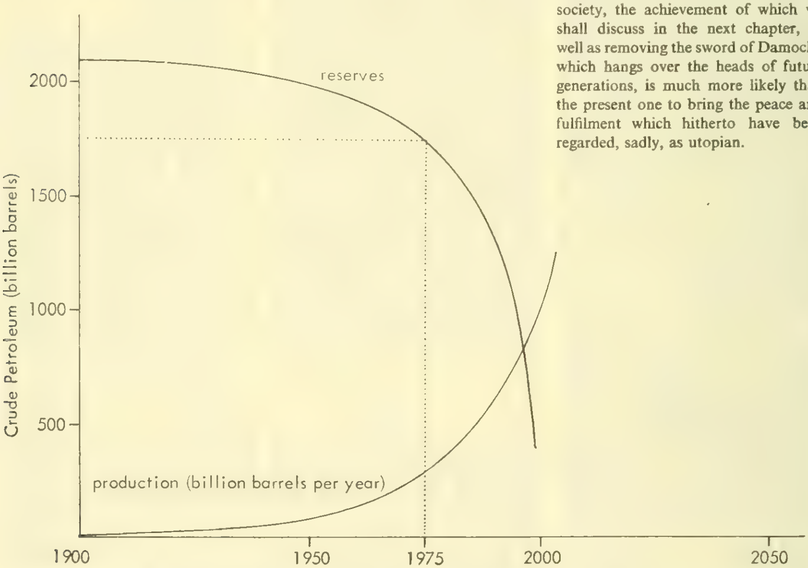

Figure 1. World reserves of crude petroleum at exponential rate of consumption. Note that in 1975, with no more than 15 years left before demand exceeds supply the total global reserve has been depleted by only 12½ per cent.

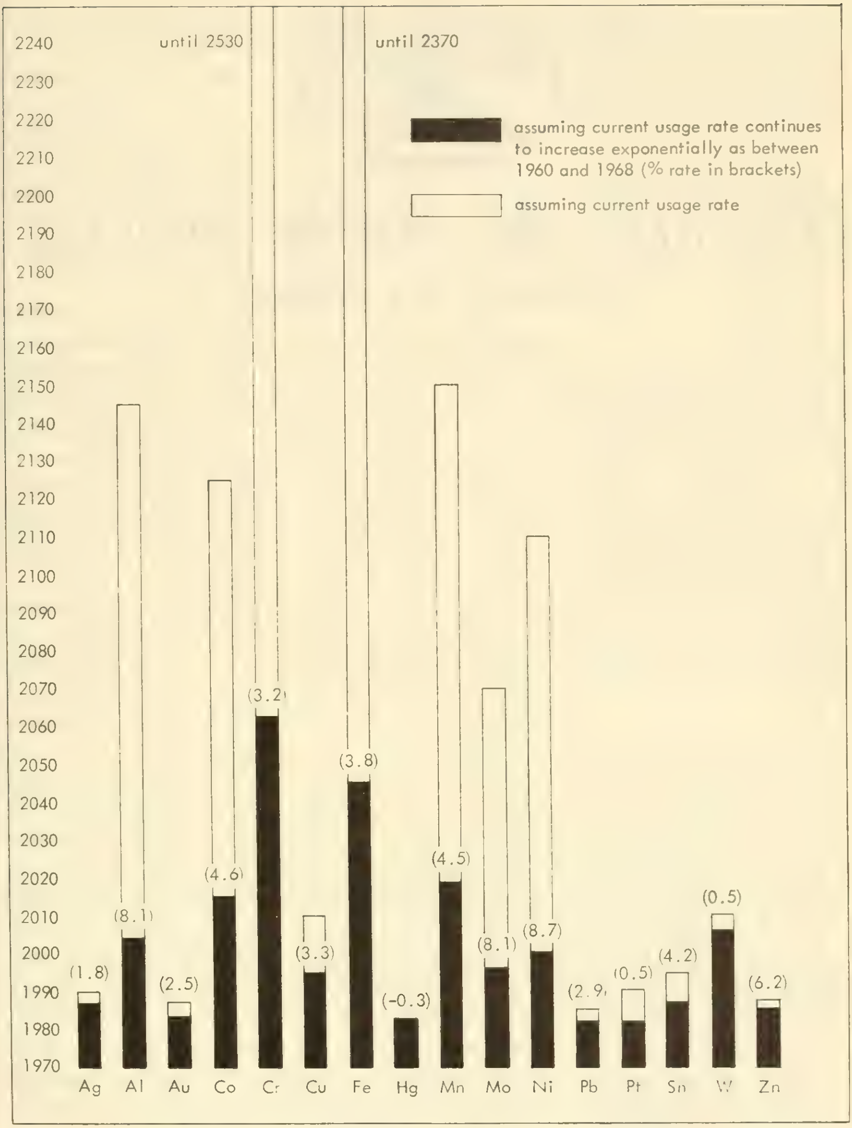

Figure 2. Mineral resources: static and exponential reserves.[7]

(For key, see page 41)

A BLUEPRINT FOR SURVIVAL

Towards the stable society:
Strategy for change

Introduction

210. The principal conditions of a stable society—one that to all intents and purposes can be sustained indefinitely while giving optimum satisfaction to its members — are: (1) minimum disruption of ecological processes; (2) maximum conservation of materials and energy—or an economy of stock rather than flow; (3) a population in which recruitment equals loss; and (4) a social system in which the individual can enjoy, rather than feel restricted by, the first three conditions.

211. The achievement of these four conditions will require controlled and well-orchestrated change on numerous fronts and this change will probably occur through seven operations: (1) a control operation whereby environmental disruption is reduced as much as possible by technical means; (2) a freeze operation, in which present trends are halted; (3) asystemic substitution, by which the most dangerous components of these trends are replaced by technological substitutes, whose effect is less deleterious in the short-term, but over the long-term will be increasingly ineffective; (4) systemic substitution, by which these technological substitutes are replaced by "natural" or self-regulating ones, i.e. those which either replicate or employ without undue disturbance the normal processes of the ecosphere, and are therefore likely to be sustainable over very long periods of time; (5) the invention, promotion and application of alternative technologies which are energy and materials conservative, and which because they are designed for relatively "closed" economic communities are likely to disrupt ecological processes only minimally (e.g. intermediate technology); (6) decentralisation of polity and economy at all levels, and the formation of communities small enough to be reasonably self-regulating and self-supporting; and (7) education for such communities.

212. As we shall see when we examine how our four conditions might be achieved, some changes will involve only a few of these operations, in others a number of the operations will be carried out almost simultaneously, and in others one will start well before another has ended. The usefulness of the operation-concept is simply to clarify the orchestration of change.

213. In putting forward these proposals we are aware that hasty or disordered change is highly disruptive and ultimately self-defeating; but we are also mindful of how the time-scale imposed on any proposal for a remedial course of action has been much-abbreviated by the dynamic of exponential growth (of population, resource depletion and pollution) and by the scarcely perceived scale and intensity of our disruption of the ecological processes on which we and all other life-forms depend. Within these limitations, therefore, we have taken care to devise and synchronise our programme so as to minimise both unemployment and capital outlay. We believe it possible to change from an expansionist society to a stable society without loss of jobs or an increase in real expenditure. Inevitably, however, there will be considerable changes, both of geography and function, in job availability and the requirements for capital inputs—and these may set up immense counter-productive social pressures. Yet given the careful and sensitive conception and implementation of a totally integrated programme these should be minimised, and an open style of government should inspire the trust and co-operation of the general public so essential for the success of this enterprise.

214. One further point should be made before we consider in more detail the various changes required. As each of the many socio-economic components or variables of industrial society are changed or replaced, so various pressure-points will be set up. It is easy to imagine, for example, a situation in which 25 per cent of the socio-economic variables are designed for a stable society and therefore by definition are ill-suited to one of expansion. This situation may create more problems than it solves. When we reach the point at which 50 per cent of the variables are adapted to stability and the other 50 per cent to expansion, the difficulties and tensions are likely to be enormous, but thereafter each change and replacement will assist further change and replacement, and the moulding of a sustainable, satisfying society should be that much easier. It is difficult for the human mind to imagine the temporal sequence of complex change, and no doubt impossible for it to visualise the precise interactions of the various components. While bearing in mind the folly of expecting computers to do our thinking for us, we believe they have an important role to play in demonstrating

the consequences throughout social and ecological systems of a great number of changes over a given period of time.

Minimising the disruption of ecological processes

220. Ecological processes can be disrupted by introducing into them either substances that are foreign to them or the correct ones in the wrong quantities. It follows therefore that the most common method of pollution "control", namely dispersal, is not control at all, but a more or less useful way of playing for time. Refuse disposal by dumping solves the immediate problem of the householder, but as dumping sites are used up it creates progressively less soluble problems for society at large; smokeless fuels are invaluable signs of progress for the citizens of London or Sheffield, but the air pollution from their manufacture brings misery and ill-health to the people near the plants where they are produced; in many cases the dispersal of pollutants through tall chimneys merely alters the proportion of pollution, so that instead of a few receiving much, many receive some; and lastly, in estuarine and coastal waters—crucial areas for fisheries—nutrients from sewage and agricultural run-off in modest quantities probably increase productivity, but in excess are as harmful as organochlorines and heavy metals.

221. Thus dispersal can be only a temporary expedient. Pollution control proper must consist of the recycling of materials, or the introduction of practices which are so akin to natural processes as not to be harmful. The long-term object of these pollution control procedures is to minimise our dependence on technology as a regulator of the ecological cycles on which we depend, and to return as much as possible to the natural mechanisms of the ecosphere, since in all but the short-term they are much more efficient and reliable. In the light of these remarks then, let us consider some contemporary pollution problems and how they might be solved.

222. *Pesticides*. There is no way of controlling the disruption caused by pesticides save by using less, and progress towards this end will probably require three operations: freeze, asystemic substitution, and systemic substitution. The freeze operation consists of the ending of any further commitment to pesticides, particularly the persistent organochlorines. For the developed countries this is a relatively simple procedure, and already the use of Dieldrin, DDT, and so on, is beginning to decline. For the undeveloped countries, however, it would be impossible without an undertaking from the developed ones to subsidise the supply of much more expensive substitutes. In the malaria control programme, for example, the replacement of DDT by malathion or propoxur would raise the cost of spraying operations from US $60 million a year to $184 million and $510 million respectively[1].

223. Once such an undertaking is given, the undeveloped countries could proceed to the second operation. (There is no conceivable reason why the developed ones should not formally do so now.) This consists of the progressive substitution of non-persistent pesticides (organophosphates, carbamates, etc.) for the organochlorines. The third operation, the substitution of natural controls for pesticides in general could follow soon after. Two important points should be borne in mind: (*a*) it is most unlikely that the third stage could ever be complete—we will probably have to rely on the precision use of pesticides for some considerable time as part of a programme of integrated control; and (*b*) the second and third operations would proceed in harness until all countries had fully integrated pest control programmes. The drawback with integrated control (the combination of biological control, mechanical control, crop-species diversity and the precise use of species-specific pesticides) is that as yet we do not know enough about it, so that a full-scale research programme is urgently required. The agro-chemical industries should be encouraged to invest in integrated control programmes though plainly, since the profits cannot be so great as from chemical control, research will need public finance—as will the training of integrated control advisory teams to assist farmers, particularly in the undeveloped countries. Such an investment, however, will appear modest once integrated control is fully operational, in comparison with the vast sums of money currently being spent annually on pesticides. A typical operational procedure for the transfer from chemical to integrated control might be as follows: organochlorines phased out, substitute pesticides phased in; in some cultivations these substitutes would be phased out almost immediately, to be replaced by integrated control; in others the time-table would be somewhat longer, depending on our understanding of the relevant agro-ecological processes and the availability of trained personnel.

224. *Fertilisers*. While on many occasions the use of inorganic fertilisers is valuable, their overuse leads to two intractable problems: the pollution of freshwater systems by run-off, and diminishing returns due to the slow but inevitable impoverishment of the soil (see appendix on food supply). Again the solution will come through three operations: freeze, asystemic substitution, and systemic substitution. The first operation requires there to be no further increment in the application of inorganic fertilisers, and hence the removal of subsidies for them. Again this is relatively easy for the developed countries (although there may be some drop in yield per acre), but next to impossible for the undeveloped countries, which are now being introduced to the new genetic hybrids of rice and wheat. Since the remarkable responsiveness of these hybrids is contingent on massive fertiliser inputs (up to 27 times present ones), the undeveloped world is faced with an unenviable choice: either to keep alive its expanding population over the next ten years at the price of considerable damage to soil structure and long-term fertility; or to improve soil structure so that a good proportion of the population can be fed indefinitely, but in the knowledge that the population will probably be reduced to that proportion by such natural processes as famine and epidemic. In the long-term, of course, the solution lies in population control; but in the intervening period there seems to be no alternative to concentrating on agricultural methods that are sustainable even at the expense of immediate productivity. The consequences of not doing so are likely to be much worse than any failure to take full advantage of the new hybrids. In the meantime, an emergency food-supply must be created by the developed prime-producers (USA, USSR, Canada, Australia, New Zealand) so that as much as possible of any short-fall can be met during this difficult period.

225. The second operation involves the gradual substitution of organic manures for inorganic fertilisers—though occasionally the latter will be used to supplement the former—and the return to such practices as rotation and leys; this would merge into the third operation: the adoption of highly diversified farming practices in place of monocultures. It is necessary to emphasise that this is not simply a return to traditional good husbandry: it is much more a change from flow fertility (whereby nutrients are imported from outside the agro-ecosystem, a proportion being utilised by food-plants, but with a large proportion leaving the agro-ecosystem in the form of run-off, etc.) to cyclic fertility (in which nutrients in the soil are used and then returned to it in as closed a cycle as possible). The great advantage of nutrients in organic form is that the soil appears much better adapted to them. The nitrogen in humus, for example, is only 0.5 per cent inorganic, the rest being in the form of rotting vegetation, decomposing insects and other animals, and animal manure. A high proportion of organic matter is essential for the soil to be easily workable over long periods (thus extending the period in which cultivations are timely), for it to retain water well without becoming saturated, for the retention of nutrients so that they remain available to plants until they are taken up by them (thus reducing wastage), and for the provision of the optimum environment for the micro-organisms so vital for long-term fertility. The rotation of leguminous plants and of grass grazed by animals are the most effective ways of adding organic matter to the soil, while at the same time allowing livestock to select their own food in the open has the double advantage that they are bred with a healthy fat-structure and their wastes enrich the soil instead of polluting waterways or overloading sewage systems. By diversifying farming in these and other ways we are taking advantage of the immense growth of knowledge about agricultural ecology, which plainly will increase with additional research.

226. *Domestic sewage*. The volume of sewage is directly proportional to population numbers and can only be stabilised or reduced by stabilising or reducing the population. However, sewage can and should be disposed of much more efficiently. It is absurd that such valuable nutrients should be allowed to pollute fresh and coastal waters, or that society should be put to the expense of disposing of them in areas where they cannot be effectively utilised. Unfortunately, in developed countries, their disposal as agricultural fertiliser is not generally feasible, largely for two reasons: (*a*) they are contaminated by industrial wastes; (*b*) transportation costs are too high. Both difficulties can be overcome—in the first case by ensuring that there is no (or negligible) admixture of industrial to domestic effluents, which depends on better industrial pollution control (see below); and in the second case by decentralising so that there is an improved mix of rural and urban activities. This will be explored in the section on social systems. In undeveloped countries, the problem of domestic sewage could be overcome by the provision of aid to pay for sewage plants that yield purified water and usable sludge.

227. *Industrial wastes*. Reduction of industrial effluent should proceed by two operations: a control operation, and an alternative (materials and energy conservative) technology operation. We have already suggested that the key to pollution control is not dispersal but recycling, and since recycling is a most important element in resource management it will be discussed in the section on stock economics. The alternative technology operation will be considered in the section on social systems.

Conversion to an economy of stock

230. The transfer from flow to stock economics can be considered under two headings: resource management and social accounting.

231. *Resource management*. It is essential that the throughput of raw materials be minimised both to conserve non-renewable resources and to cut down pollution. Since industry must have an economic incentive to be conservative of materials and energy and to recycle as much as possible, we propose a number of fiscal measures to these ends:
(*a*) A raw materials tax. This would be proportionate to the availability of the raw material in question, and would be designed to enable our reserves to last over an arbitrary period of time, the longer the better, on the principle that during this time our dependence on this raw material would be reduced. This tax would penalise resource-intensive industries and favour employment-intensive ones. Like (*b*) below it would also penalise short-lived products.
(*b*) An amortisation tax. This would be proportionate to the estimated life of the product, e.g. it would be 100 per cent for products designed to last no more than a year, and would then be progressively reduced to zero per cent for those designed to last 100+ years. Obviously this would penalise short-lived products, especially disposable ones, thereby reducing resource utilisation and pollution, particularly the solid-waste problem. Plastics, for example, which are so remarkable for their durability, would be used only in products where this quality is valued, and not for single trip purposes. This tax would also encourage craftmanship and employment-intensive industry.

232. The raw materials tax would obviously encourage recycling, and we can see how it might work if we consider such a vital resource as water. The growing conflict between farmers, conservationists and the water boards is evidence enough that demand for water is conflicting with other, no less important, values. At the moment, the water boards have no alternative but to fulfil their statutory obligation to meet demand, and accordingly valley after valley comes under the threat of drowning. Clearly, unless we consider dry land an obstacle to progress, demand must be stabilised, and since demand is a function of population numbers $\times$ *per capita* consumption, both must be stabilised, if not reduced (and we have seen that for other reasons they must be reduced). To this end therefore, while a given minimum can be supplied to each person free-of-charge, any amount above that minimum should be made increasingly expensive. As far as industry is concerned, the net effect would be to encourage the installation of closed-circuit systems for water; total demand would be reduced, and there would be less pressure on lowland river systems.

233. Despite the stimulus of a raw materials tax, however, it is likely that there would be a number of serious pollutants which it would be uneconomic to recycle, and still others for which

recycling would be technically impossible. One thinks in particular of the radioactive wastes from nuclear power stations. Furthermore, recycling cannot do everything: there will always be a non-recoverable minimum, which as now will have to be disposed of as safely as possible. This limitation can be made clear if we postulate a 3 per cent growth rate, and the introduction of pollution controls which reduce pollution by 80 per cent throughout—it would then take only 52 years to bring us back where we started from, with the original amount of pollution but with a much greater problem of reducing it any further; if we had a 6 per cent growth rate, we would reach this position in a mere 26 years. It is also worth mentioning that recycling consumes energy and is therefore polluting, so that it is necessary to develop recycling procedures which are energy conservative.

234. The problem of uneconomic recycling can be resolved by the granting of incentives by government. Indeed, in the short-term, the entire recycling industry should be encouraged to expand, even though we know that in the long-term industrial expansion is self-defeating. This brings us to the intractable problem of the disposal of the undisposable, which can only be resolved by the termination of industrial growth and the reduction of energy demand. Again fiscal measures will be supremely important, and we propose one in particular: (*c*) A power tax. This would penalise power-intensive processes and hence those causing considerable pollution. Since machinery requires more power than people, it would at the same time favour the employment intensification of industry, i.e. create jobs. It would also penalise the manufacture of short-lived products. In addition to this tax, there should be financial incentives for the development and installation of total energy systems, a matter to which we shall return in the section on social systems.

235. Finally, industrial pollution can also be reduced by materials substitution. The substitution of synthetic compounds for naturally occurring compounds has created serious environmental damage since in some cases the synthetics can be broken down only with difficulty and in others not at all. The usage rate of these synthetics has increased immensely at the expense of the natural products, as can be seen from the following examples[2]:

(*a*) In the US, *per capita* consumption of synthetic detergents increased by 300 per cent between 1962 and 1968. They have largely replaced soap products, *per capita* consumption of which fell by 71 per cent between 1944 and 1964.

(*b*) Synthetic fibres are rapidly replacing cotton, wool, silk and other natural fibres. In the US, *per capita* consumption of cotton fell by 33 per cent between 1950 and 1968.

(*c*) The production of plastics and synthetic resins in the US, has risen by 300 per cent between 1958 and 1968. They have largely replaced wood and paper products.

All of these processes consume the non-renewable fossil fuels, and their manufacture requires considerable inputs of energy. On the face of it, therefore, a counter-substitution of naturally occurring products would much reduce environmental disruption. However, it is possible that such a change-over, while it would certainly reduce disruption at one end, might dangerously increase it at the other. For example, many more acres would have to be put under cotton, thus increasing demand for pesticides, more land would have to be cleared and put under forest monocultures, and so on. This problem can only be solved by reducing total consumption.

236. *Genetic resources.* Before leaving the subject of resources, it is appropriate that we consider the world's diminishing stock of genetic resources. Genetic diversity is essential for the security of our food supply, since it is the *sine qua non* of plant breeding and introduction. The greater the number of varieties, the greater the opportunities for developing new hybrids with resistance to different types of pests and diseases, and to extremes of climate. It is important that new hybrids be continually developed since resistance to a particular disease is never a permanent quality. The number of plant varieties to be found in nature is infinitely greater than the number we could create artificially. Most of them are to be found in the undeveloped countries either as traditional domesticated plants or as wild plants in habitats relatively unaltered by man. There is a real danger that the former will be replaced by contemporary high-yield varieties, while the latter will disappear when their habitats are destroyed. An FAO conference in 1967 concluded that the plant-gene pool has diminished dangerously, for all over the world centres of diversity, our gene banks as it were, are disappearing, and with them our chance of maintaining productivity in food[3].

237. Such centres—areas of wilderness—are often destroyed because their importance is not understood. Because they seem less productive than fields of waving corn, or because they are not accessible or attractive to tourists, they are considered in need of "improvement" or development, or simply as suitable dumping grounds for the detritus of civilisation. This is particularly true of wetlands—estuaries and marshes—where pollution, dredging, draining and filling are looked on almost with equanimity, certainly with scant regard for what is being lost. Yet the complex of living and decomposing grasses, and of phytoplankton, characteristic of wetlands, supports vast numbers of fish and birds and makes it one of the world's most productive ecosystems. Estuaries are the spawning grounds of very many fish and shellfish and form the base of the food-chain of some 60 per cent of our entire marine harvest. Should they go we can expect a substantial drop in productivity.

238. It is vital to the future well-being of man that wilderness areas and wetlands be conserved at all costs. This cannot be a matter simply of taking seed and storing it, since to be valuable genetic stock must continue to be subject to normal environmental pressures, and besides we have scarcely any idea of what plants we shall find useful in the future. For these reasons we must not only conserve large areas of natural habitat, we must also draw upon the knowledge and experience of the hunter-gatherers and hunter-farmers who gain their livelihood from them.

239. We therefore have recommended to the UN Human Environment Conference that[4]:

(1) Certain wilderness areas of tropical rain forest, tropical scrub forest, and arctic tundra be declared inviolate, these being the least understood and most fragile biomes;

(2) the hunter-gatherers and hunter-farmers within these areas be given title to their lands (i.e. those lands in which

traditionally they have gained their living) and be allowed to live there without pressure of any kind;

(3) severe restrictions be placed on entry to these areas by anyone who does not live there permanently (while allowing the indigenes free movement);

(4) sovereignty over the areas remain with the countries in which they lie; who should also be responsible for the policing of their boundaries;

(5) funds for administration of these areas and payments in lieu of exploitation (to the host country) be collected from UN members in proportion to their GNP;

(6) an international body be appointed as an outcome of the Stockholm Human Environment Conference to supervise an ecological programme of research, the results of which should be freely available to participating countries.

240. *Social accounting*. By the introduction of monetary incentives and disincentives it is possible to put a premium on durability and a penalty on disposability, thereby reducing the throughput of materials and energy so that resources are conserved and pollution reduced. But another important way of reducing pollution and enhancing amenity is by the provision of a more equitable social accounting system, reinforced by anti-disamenity legislation. Social accounting procedures must be used not just to weigh up the merits of alternative development proposals, but also to determine whether or not society actually wants such development. Naturally, present procedures require improvement: for example, in calculating "revealed preference" (the values of individuals and communities as "revealed" to economists by the amount people are willing and/or can afford to pay for or against a given development), imagination, sensitivity and commonsense are required in order to avoid the imposition on poor neighbourhoods or sparsely inhabited countryside of nuclear power stations, reservoirs, motorways, airports, and the like; and in calculating the "social time preference rate" (an indication of society's regard for the future) for a given project, a very low discount should be given, since it is easier to do than undo, and we must assume that unless we botch things completely many more generations will follow us who will not thank us for exhausting resources or blighting the landscape.

241. The social costs of any given development should be paid by those who propose or perpetrate it—"the polluter must pay" is a principle that must guide our costing procedures. Furthermore, accounting decisions should be made in the light of stock economics: in other words, we must judge the health of our economy not by flow or throughput, since this inevitably leads to waste, resource depletion and environmental disruption, but by the distribution, quality and variety of the stock. At the moment, as Kenneth Boulding has pointed out[5], "the success of the economy is measured by the amount of throughput derived in part from reservoirs of raw materials, processed by 'factors of production', and passed on in part as output to the sink of pollution reservoirs. The Gross National Product (GNP) roughly measures this throughput". Yet, both the reservoirs of raw materials and the reservoirs for pollution are limited and finite, so that ultimately the throughput from the one to the other must be detrimental to our well-being, and must therefore not only be minimised but be regarded as a cost rather than a benefit. For this reason Boulding has suggested that GNP be considered a measure of gross national cost, and that we devote ourselves to its minimisation, maximising instead the quality of our stock. "When we have developed the economy of the spaceship earth", he writes, "in which man will persist in equilibrium with his environment, the notion of the GNP will simply disintegrate. We will be less concerned with income-flow concepts and more with capital-stock concepts. Then technological changes that result in the maintenance of the total stock with *less* throughput (less production and consumption) will be a clear gain". We must come to assess our standard of living not by calculating the value of all the air-conditioners we have made and sold, but by the freshness of the air; not by the value of the antibiotics, hormones, feedstuff and broiler-houses, and the cost of disposing of their wastes, all of which put so heavy a price on poultry production today, but by the flavour and nutritional quality of the chickens themselves; and so on. In other words, accepted value must reflect real value, just as accepted cost must reflect real cost.

242. It is evident, however, that in a society such as ours, which to a large extent ignores the long-term consequences of its actions, there is a substantial differential between accepted cost and real cost. An industrial town, for example, whose citizens and factories pollute the air and water systems around it and who feed themselves from a number of increasingly intensive monocultures, not only has no way of measuring the satisfactions or otherwise afforded by its life-style, nor of equitably distributing the costs imposed by one polluter on another, but no way either of assessing ecological costs, some of which will have to be paid by generation 1, others by generations 2, 3, 4, etc., and still others by people elsewhere, with whom in every other respect there might be no contact. Thus its agricultural practices might provide cheap and plentiful food for one generation and stimulate its agro-chemical industries, but may so impoverish the soil and disrupt the agro-ecosystem, that the next generation will have to import more food, or failing this, to resort to still riskier expedients, thereby seriously compromising the food supply of the following generation; or the wastes of one generation might affect the health of the next, or its marine food supply, or so increase the mutation rate that future generations receive an unlooked for genetic burden. The extent to which we are simplifying ecosystems and destroying natural controls so that we are forced to provide technological substitutes is a real cost against society and should be accounted as one. At the moment, however, we merely add up the value of mining operations, factories and so on, and that of cleaning up the mess whenever we attempt to do so, and conclude that we have never been better off.

243. Since the full costs of any action anywhere in the world must be borne by someone, somewhere, sometime, it is important that our accounting system makes provision for this. We accept, however, that ecological processes are so complex, and can spread so far in space and time, that this will be exceptionally difficult. Nonetheless, given the truism that a satisfactory accounting system is one which supports and helps perpetuate the social system from which it derives, we must attempt to devise one which is fitted to a society based on a sober assessment of ecological reality and not on the

anthropocentric pipe-dream that we can do what we will to all species, not excepting, it seems, future generations of our own. It is worth recalling Prof. Commoner's dictum that since economics is the science of the distribution of resources, all of which are derived from the ecosphere, it is foolish to perpetuate an economic system which destroys it. Ideally (and as befits the etymology of the two words), ecology and economics should not be in conflict: ecology should provide the approach, the framework for an understanding of the interrelationships of social and environmental systems; and economics should provide the means of quantifying those interrelationships in the light of such an understanding, so that decisions on alternative courses of action can be made without undue difficulty.

244. One of our long-term goals, therefore, must be to unite economics and ecology. The specific measures we have proposed are, we believe, necessary steps in this direction, albeit crude ones. A raw materials tax, an amortisation tax, a power tax, revised methods of calculating revealed preference, social time preference rate, and so on, with legislative provision for their enforcement, a set of air, water and land quality standards enforceable at law and linked with a grant-incentive programme—these and other measures will have to be introduced at an early stage. Naturally, the full force of such measures could not be allowed to operate immediately: they would have to be carefully graded so as to be effective without causing unacceptable degrees of social disturbance. Plainly the social consequences will be great, and these will be considered in the section on social systems. The key to success is likely to be careful synchronisation, and this too will be considered in a separate section.

Stabilising the population

250. We have seen already that however slight the growth rate, a population cannot grow indefinitely. It follows, therefore, that at some point it must stabilise of its own volition, or else be cut down by some "natural" mechanism —famine, epidemic, war, or whatever. Since no sane society would choose the latter course, it must choose to stabilise. To do this it must have some idea of its optimum size, since again it is unlikely that any sane society would choose to stabilise above (or indeed below) it.

251. The two main variables affected by population numbers, as opposed to *per capita* consumption, are the extent to which the emotional needs and social aspirations of the community can be met (i.e. the complex of satisfactions which has come to be known as the quality of life), and the community's ability to feed itself. In our opinion there is good social and epidemiological evidence that Britain and many other countries in both the developed and undeveloped worlds are overcrowded. However, since this is impossible to prove, and since there is immense variation in individual emotional requirements, it would be unwise in the present state of our knowledge to rely on quality of life judgements when calculating the optimum population. Fortunately, we know much more about feeding ourselves, and assessment of the optimum becomes a realisable task if we base it on the simple ecological concept of the carrying capacity of the land.

252. Carrying capacity is usually defined as the amount of solar energy potentially available to man via food-plants in a given area. This definition must be accompanied by a caveat to the effect that if carrying capacity is considered in terms of energetics alone, a number of essential ecological and nutritional variables are in danger of exclusion. For example, it would be easy to assume that land used for a combination of purposes (mixed farming, woodland, etc.) would be better employed and could support a larger population if it were exclusively given over to the intensive production of food-plants high in calories (e.g. wheat). We know, however, that protein and the other nutrients are no less vital to us than calories, while there is evidence that we are more likely to get the proper nutritional components from meat if it comes to us from free-living animals. This requirement alone demands a certain diversity, both of species and habitat, and we have seen too (in the appendix on ecosystems) that diversity is essential if fertility and stability are to be maintained over the long-term.

253. As we have seen Britain supports a population well in excess of the carrying capacity of the land owing to its ability to import large amounts of food, especially the cheap protein required to feed our poultry and pigs. As world population grows, and with it global agricultural demand, so will it be increasingly difficult for us to find countries with exportable surpluses, surpluses which in any case will become progressively more expensive. Unless we are willing (and able) to perpetuate an even greater inequality of distribution than exists today, Britain must be self-supporting. We have stated already our belief that on the evidence available it is unlikely that there will be any significant increase in yield per acre, so that there is no other course open to us but to reduce our numbers before we stabilise. Since we appear capable of supporting no more than half our present population, the figure we should aim for over the next 150 to 200 years can be no greater than 30 million, and in order to protect it from resource fluctuation probably less.

254. Not every country is in such a difficult position as Britain. A few will be able to stabilise at or relatively near present levels. But taking world population as a whole, and using *per capita per diem* protein intake as the key variable in assessing carrying capacity, we believe the optimum population for the world is unlikely to be above 3,500 million and is probably a good deal less. This figure rests on three assumptions: (*a*) that the average *per capita per diem* requirements of protein is 65 grams[6]; (*b*) that present agricultural production *per capita* can be sustained indefinitely; and (*c*) that there is absolutely equitable distribution, no country enjoying a greater *per capita per diem* protein intake than any other—which compared with today's conditions is absurdly utopian. Utopian though they may be, unless these assumptions are realised, we are faced either with the task of reducing world population still further until it is well below the optimum, or with condoning inequalities grosser and more unjust than those which we in the developed countries foster at present.

255. While they cannot grow indefinitely, populations can remain above the optimum—indeed above the sustainable maximum—for some time. The fact that the global population, including that of Britain, is above both levels, means only that our numbers are

preventing the optimisation of other values. It means that while most people receive the bare minimum of calories necessary for survival, a large proportion are deprived of the nutrients (especially protein) essential for intellectual development. They are alive, but unable to realise their full potential —which is the grossest possible waste of human resources. An optimum population, therefore, may be defined as one that can be sustained indefinitely and at a level at which the other values of its members are optimised—and the fact that we are above this level does not justify despair, but does justify a great sense of urgency in working towards our long-term goal of the optimum. For it is obvious that given the dynamic of population growth, even if all nations today determined to stabilise their populations, numbers would continue to rise for some considerable time. Indeed the Population Council has calculated (Annual Report 1970) that "... if the replacement-sized family is realised for the world as a whole by the end of this century—itself an unlikely event—the world's population will then be 60 per cent larger or about 5.8 billion, and due to the resulting age structure it will not stop growing until near the end of the next century, at which time it will be about 8.2 billion (8,200 million) or about 225 per cent the present size. If replacement is achieved in the developed world by 2000 and in the developing world by 2040, then the world's population will stabilise at nearly 15.5 billion (15,500 million) about a century hence, or well over four times the present size". Clearly we must go all out for the "unlikely event" of achieving the replacement-sized family (an average of about two children per couple) *throughout the world by the end of this century*, if our children are not to suffer the catastrophes we seek to avoid.

256. Our task is to end population growth by lowering the rate of recruitment so that it equals the rate of loss. A few countries will then be able to stabilise, to maintain that ratio; most others, however, will have to slowly *reduce* their populations to a level at which it is sensible to stabilise. Stated baldly, the task seems impossible; but if we start now, and the exercise is spread over a sufficiently long period of time, then we believe that it is within our capabilities. The difficulties are enormous, but they are surmountable.

257. First, governments must acknowledge the problem and declare their commitment to ending population growth; this commitment should also include an end to immigration. Secondly, they must set up national population services with a fourfold brief:

(1) to publicise as widely and vigorously as possible the relationship between population, food supply, quality of life, resource depletion, etc., and the great need for couples to have no more than two children. The finest talents in advertising should be recruited for this, and the broad aim should be to inculcate a socially more responsible attitude to child-rearing. For example, the notion (derived largely from the popular women's magazines) that childless couples should be objects of pity rather than esteem should be sharply challenged; and of course there are many similar notions to be disputed.

(2) to provide at local and national levels free contraception advice and information on other services such as abortion and sterilisation;

(3) to provide a comprehensive domiciliary service, and to provide contraceptives free of charge, free sterilisation, and abortion on demand;

(4) to commission, finance, and coordinate research not only on demographic techniques and contraceptive technology, but also on the subtle cultural controls necessary for the harmonious maintenance of stability. We know so little about the dynamics of human populations that we cannot say whether the first three measures would be sufficient. It is self-evident that if couples still wanted families larger than the replacement-size no amount of free contraception would make any difference. However, because we know so little about population control, it would be difficult for us to devise any of the socio-economic restraints which on the face of it are likely to be more effective, but which many people fear might be unduly repressive. For this reason, we would be wise to rely on the first three measures for the next 20 years or so. We then may find they are enough—but if they aren't, we must hope that intensive research during this period will be rewarded with a set of socio-economic restraints that are both *effective* and *humane*. These will then constitute the third stage, and should also provide the tools for the fourth stage—that of persuading the public to have average family sizes of slightly *less* than replacement size, so that total population can be greatly reduced. If we achieve a decline rate of 0.5 per cent per year, the same as Britain's rate of growth today, there should be no imbalance of population structure, as the dependency ratio would be exactly the same as that of contemporary Britain. Only the make-up of dependency would be different: instead of there being more children than old people, it would be the other way round. The time-scale for such an operation is long of course, and this will be suggested in the section on orchestration.

Creating a new social system

260. Possibly the most radical change we propose in the creation of a new social system is decentralisation. We do so not because we are sunk in nostalgia for a mythical little England of fetes, olde worlde pubs, and perpetual conversations over garden fences, but for four much more fundamental reasons:

261. (*a*) While there is good evidence that human societies can happily remain stable for long periods, there is no doubt that the long transitional stage that we and our children must go through will impose a heavy burden on our moral courage and will require great restraint. Legislation and the operations of police forces and the courts will be necessary to reinforce this restraint, but we believe that such external controls can never be so subtle nor so effective as internal controls. It would therefore be sensible to promote the social conditions in which public opinion and full public participation in decision-making become as far as possible the means whereby communities are ordered. The larger a community the less likely this can be: in a heterogeneous, centralised society such as ours, the restraints of the stable society if they were to be effective would appear as so much outside coercion; but in communities small enough for the general will to be worked out and expressed by individuals confident of themselves and their fellows as individuals, "us and them" situations are less likely to occur—people having learned the limits of a stable society would be free to order their own lives

within them as they wished, and would therefore accept the restraints of the stable society as necessary and desirable and not as some arbitrary restriction imposed by a remote and unsympathetic government.

262. (*b*) As agriculture depends more and more on integrated control and becomes more diversified, there will no longer be any scope for prairie-type crop-growing or factory-type livestock-rearing. Small farms run by teams with specialised knowledge of ecology, entomology, botany, etc., will then be the rule, and indeed individual smallholdings could become extremely productive suppliers of eggs, fruit and vegetables to neighbourhoods. Thus a much more diversified urban-rural mix will be not only possible, but because of the need to reduce the transportation costs of returning domestic sewage to the land, desirable. In industry, as with agriculture, it will be important to maintain a vigorous feedback between supply and demand in order to avoid waste, overproduction, or production of goods which the community does not really want, thereby eliminating the needless expense of time, energy and money in attempts to persuade it that it does. If an industry is an integral part of a community, it is much more likely to encourage product innovation because people clearly want qualitative improvements in a given field, rather than because expansion is necessary for that industry's survival or because there is otherwise insufficient work for its research and development section. Today, men, women and children are merely consumer markets, and industries as they centralise become national rather than local and supranational rather than national, so that while entire communities may come to depend on them for the jobs they supply, they are in no sense integral parts of those communities. To a considerable extent the "jobs or beauty" dichotomy has been made possible because of this deficiency. Yet plainly people want jobs *and* beauty, they should not in a just and humane society be forced to choose between the two, and in a decentralised society of small communities where industries are small enough to be responsive to each community's needs, there will be no reason for them to do so.

263. (*c*) The small community is not only the organisational structure in which internal or systemic controls are most likely to operate effectively, but its dynamic is an essential source of stimulation and pleasure for the individual. Indeed it is probable that only in the small community can a man or woman be an individual. In today's large agglomerations he is merely an isolate—and it is significant that the decreasing autonomy of communities and local regions and the increasing centralisation of decision-making and authority in the cumbersome bureaucracies of the state, have been accompanied by the rise of self-conscious individualism, an individualism which feels threatened unless it is harped upon. Perhaps the two are mutually dependent. It is no less significant that this self-conscious individualism tends to be expressed in ways which cut off one individual from another—for example the accumulation of material goods like the motor-car, the television set, and so on, all of which tend to insulate one from another, rather than bring them together. In the small, self-regulating communities observed by anthropologists, there is by contrast no assertion of individualism, and certain individual aspirations may have to be repressed or modified for the benefit of the community—yet no man controls another and each has very great freedom of action, much greater than we have today. At the same time they enjoy the rewards of the small community, of knowing and being known, of an intensity of relationships with a few, rather than urban man's variety of innumerable, superficial relationships. Such rewards should provide ample compensation for the decreasing emphasis on consumption, which will be the inevitable result of the premium on durability which we have suggested should be established so that resources may be conserved and pollution minimised. This premium, while not diminishing our real standard of living, will greatly reduce the turnover of material goods. They will thus be more expensive, although once paid for they should not need replacing except after long periods. Their rapid accumulation will no longer be a realisable, or indeed socially acceptable goal, and alternative satisfactions will have to be sought. We believe a major potential source of these satisfactions to be the rich and variegated interchanges and responsibilities of community life, and that these are possible only when such communities are on a human scale.

264. (*d*) The fourth reason for decentralisation is that to deploy a population in small towns and villages is to reduce to the minimum its impact on the environment. This is because the actual urban superstructure required per inhabitant goes up radically as the size of the town increases beyond a certain point. For example, the *per capita* cost of high rise flats is much greater than that of ordinary houses; and the cost of roads and other transportation routes increases with the number of commuters carried. Similarly, the *per capita* expenditure on other facilities such as those for distributing food and removing wastes is much higher in cities than in small towns and villages. Thus, if everybody lived in villages the need for sewage treatment plants would be somewhat reduced, while in an entirely urban society they are essential, and the cost of treatment is high. Broadly speaking, it is only by decentralisation that we can increase self-sufficiency—and self-sufficiency is vital if we are to minimise the burden of social systems on the ecosystems that support them.

265. Although we believe that the small community should be the basic unit of society and that each community should be as self-sufficient and self-regulating as possible, we would like to stress that we are not proposing that they be inward-looking, self-obsessed or in any way closed to the rest of the world. Basic precepts of ecology, such as the interrelatedness of all things and the far-reaching effects of ecological processes and their disruption, should influence community decision-making, and therefore there must be an efficient and sensitive communications network between all communities. There must be procedures whereby community actions that affect regions can be discussed at regional level and regional actions with extra-regional effects can be discussed at global level. We have no hard and fast views on the size of the proposed communities, but for the moment we suggest neighbourhoods of 500, represented in communities of 5,000, in regions of 500,000, represented nationally, which in turn as today should be represented globally. We emphasise that our goal should be to create *community feeling* and *global awareness*,

rather than that dangerous and sterile compromise which is nationalism.

266. In many of the developed countries where community feeling has been greatly eroded and has given way to heterogeneous congeries of strangers, the task of re-creating communities will be immensely difficult. In many of the undeveloped countries, however, although it will not be easy, because the process of community collapse and flight to the city has begun only recently there is a real chance that it can be halted by such means as the abandonment of large-scale industrial projects for the development of intermediate technologies at village level; and the provision of agro-ecological training teams so that communities can be taught to manage the land together, rather than encourage farmers to turn to expensive and dangerous procedures like the heavy use of pesticides and fertilisers, which tend to reduce the number of people needed on the land.

267. At home, industry will play a leading role in the programme to decentralise our economy and society. The discussion of taxes, antidisamenity legislation, and enforceable targets for air, land and water quality in the section on stock economics might lead some to believe that we are willing to bring about the collapse of industry, widespread unemployment, and the loss of our export markets. It is therefore worth emphasising that we wish strongly to avoid all three, and we do not see that they are necessary or inevitable consequences of our proposals. It is obvious that for as long as we depend on imports for a significant proportion of our food, so we must export. And since we are likely to require food-imports for the next 150 years, we are left with the question of whether it is possible to develop community industries, dedicated to the principles of maximal use/recycling of materials and durability of goods, and at the same time to earn an adequate revenue from exports.

268. We believe that the answer is yes, if the change-over is conducted in two stages. The first stage is to alter the direction of growth so that it becomes more compatible with the aims of a stable society. We have already mentioned that the recycling industry must be encouraged to expand, and it is obvious that willy-nilly it will do so as over the years taxes and quality targets become more stringent. To give a clearer idea of how the direction can be altered we will consider briefly the question of transport.

269. There are more than 12 million cars in Britain today, and according to the Automobile Association this figure will rise to 21 million by 1981. About half the households in Britain own a car today, and presumably the car population is expected to rise in response to a rise in this proportion, though presumably too, more households will own more than one car. At all events we have sufficient experience of traffic congestion in our towns and cities and the rape of countryside and community by ring-roads and motorways to realise that the motor-car is by no means the best way of democratising mobility. Indeed, if every household had a car, we would be faced with the choice of leaving towns and country worth driving to and thereby imposing immobility on the motorist, or of providing him with the vast expanses of concrete which are becoming increasingly necessary to avoid congestion at the expense of the areas they sterilise and blight.

270. No-one can contemplate with equanimity the doubling of roads within this decade necessary to maintain the *status quo*, and we must therefore seek sensible transportation alternatives. It is clear that broadly-speaking the only alternative is public transport—a mix of rapid mass-transit by road and rail. Rail especially should never have been allowed to run down to the extent that it has. The power requirements for transporting freight by road are five to six times greater than by rail and the pollution is correspondingly higher. The energy outlay for the cement and steel required to build a motorway is three to four times greater than that required to build a railway, and the land area necessary for the former is estimated to be four times more than for the latter. Public transport whether by road or rail is much more efficient in terms of *per capita* use of materials and energy than any private alternative. It can also be as flexible, provided it is encouraged at the expense of private transport.

271. This is the key to the provision of a sound transportation system. First the vicious spiral of congestion slowing buses, losing passengers, raising fares, losing more passengers, using more cars, creating more congestion, etc., must be broken. A commitment to build no more roads and to use the capital released to subsidise public transport would be an excellent way of doing this. The men who would normally live by roadbuilding could be diverted to clearing derelict land and restoring railways and canals as part of a general programme of renewal. From there, the progressive imposition of restrictions on private transport and the stimulation of public transport so that it could provide a fast, efficient and flexible alternative would be a matter of course. Within the motor industry, the decline in production of conventional private vehicles would be compensated for by the increased production of alternative mass-transit systems. There would also be a switch of capital and manpower to the re-development of railway systems. In the long term, however, decentralisation will bring a diminished demand for mobility itself. As Stephen Boyden has pointed out[7], people use their cars for four main reasons: to go to work, to go to the countryside, to visit friends and relations, and to show off. In the stable society, however, each community will provide its own jobs, there will be countryside around it, most friends and relations will be within it, and there will be much more reliable and satisfying ways of showing off.

272. This brings us to the second stage of the change-over, in which industry turns to the invention, production, and installation of technologies that are materials and energy conservative, that are flexible, non-polluting and durable, employment-intensive and favouring craftsmanship. Progress as we conceive of it today consists in increasing an already arbitrarily high ratio of capital to job availability; but if instead this ratio were to be reduced, then our manpower requirement would go up, while at the same time the pollution which is the inevitable by-product of capital growth would be cut down. The switch in emphasis from quantity to quality will not only stimulate demand for manpower, it will also stabilise it *and* give much greater satisfaction to the men themselves. Instead of men being used as insensate units to produce increasing quantities of components,

they should be trained and given the opportunity to improve the quality of their work. The keynotes of the manufacturing sector should come to be durability and craftsmanship—and such a premium on quality should assure us an export revenue large enough for us to continue buying food from abroad, while providing our manpower with more enjoyable occupations. In the case of industries like the aircraft industry, which would naturally have a greatly reduced role in the stable society, their engineering expertise could be turned to the development of such things as total energy systems—designed to provide the requirements of a decentralised society with the minimum of environmental disruption.

273. Industry can completely fulfil its new role only in close harmony with particular communities, so that the unreal distinction between men as employees and men as neighbours can be abandoned, and jobs then given on the basis that work must be provided by the community for the sake of that community's stability and not because one group wishes to profit from another group's labour or capital as the case may be. As industry decentralises so will the rest of society. The creation of communities will come from the combination of industrial change and a conscious drive to re-structure society.

274. The principal components of this drive are likely to be the redistribution of government and the gradual inculcation of a sense of community and the other values of a stable society. Over a stated period of time, local government should be strengthened and as many functions as possible of central government should be transferred to it. The redistribution of government should proceed on the principle that issues which affect only neighbourhoods should be decided by the neighbourhood alone, those which affect only communities by the community alone, those which affect only regions by the region alone, and so on. As regions, communities and neighbourhoods come increasingly to run their own affairs, so the development of a sense of community will proceed more easily, though we do not pretend that it will be without its problems.

275. Those regions which still have or are close to having a good urban-rural mix will be able to effect a relatively smooth transfer, but highly urbanised areas like London, the Lancashire conurbation, and South Wales will find it much more difficult to re-create communities. Nevertheless, even in London the structural remains of past communities (like the villages of Putney, Highgate, Hackney, Islington, etc.) will provide the physical nuclei of future communities—the means of orienting themselves so that they can cut themselves away from those deserts of commerce and packaged pleasure (of which the most prominent example is the Oxford Street, Regent Street, Piccadilly complex) on which so much of London's life is currently focused.

276. It is self-evident that no amount of legislative, administrative or industrial change will create stable communities if the individuals who are meant to comprise them are not fitted for them. As soon as the best means of inculcating the values of the stable society have been agreed upon, they should be incorporated into our educational systems. Indeed, it may not be until the generation of 40–50 year olds have been educated in these values (so that as far as possible everybody up to the age of 50 understands them) that stable communities will achieve sufficient acceptance for them to be permanently useful.

Orchestration

280. A cardinal assumption of this strategy is that it will not succeed without the most careful synchronisation and integration. We cannot say of a particular section of these proposals that it alone is acceptable, and therefore we will go ahead with it immediately but consider the rest later on! This section, therefore, is devoted to a schematic, annotated outline of how change might be orchestrated. It is necessarily unsophisticated and oversimplified, but we hope it will give some idea of how change in one quarter will aid change in the others.

281. Variables included in schematic outline:

(a) establishment of national population service

(b) introduction of raw materials, amortisation and power taxes; anti-disamenity legislation; air, land and water quality targets; recycling grants; revised social accounting systems

(c) developed countries end commitment to persistent pesticides and subsidise similar move by undeveloped countries

(d) end of subsidies on inorganic fertilisers

(e) grants for use of organics and introduction of diversity

(f) emergency food programme for undeveloped countries

(g) progressive substitution of non-persistent for persistent pesticides

(h) integrated control research programme

(i) integrated control training programme

(j) substitution of integrated control for chemical control

(k) progressive introduction of diversified farming practices

(l) end of road building

(m) clearance of derelict land and beginning of renewal programme

(n) restrictions on private transport and subsidies for public transport

(o) development of rapid mass-transit

(p) research into materials substitution

(q) development of alternative technologies

(r) decentralisation of industry: part one (redirection)

(s) decentralisation of industry: part two (development of community types)

(t) redistribution of government

(u) education research

(v) teacher training

(w) education

(x) experimental community

(y) domestic sewage to land

(z) target date for basic establishment of network of self-sufficient, self-regulating communities.

282. Notes:

(1) should be operating fully by 1980; review in 1995—if replacement-size families improbable by 2000, bring in socio-economic restraints; UK population should begin to slowly decline from 2015–2020 onwards; world population from 2100; little significant feedback expected in UK until about 2030.

(2) progressive; ironing out run to eliminate inconsistencies up to 1980; thereafter revise and tighten every five years; increasingly significant feedback from 1980 onwards, stimulating materials-energy conservation, employment-intensive industry, decen-

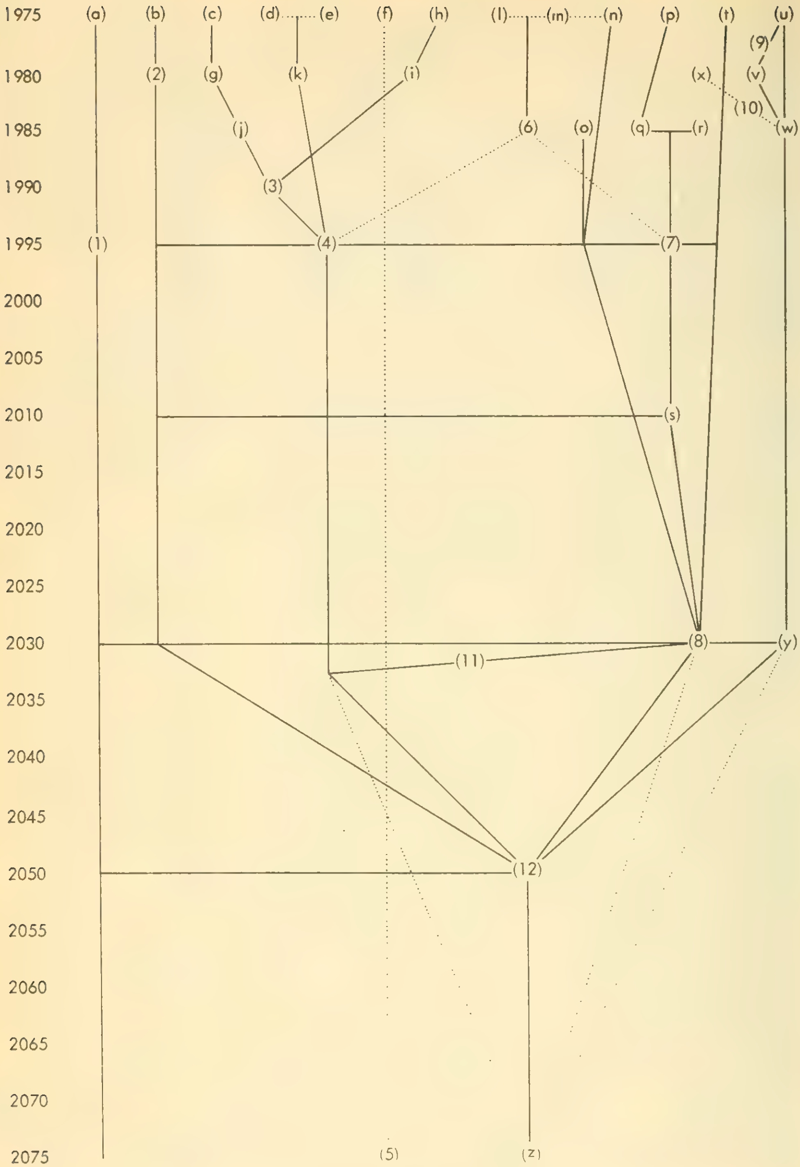

Figure 3 Schematic outline of change.
(See text for key)

tralisation, and progress in direction of (p), (q), (r) and (s).

(3) limited substitution of integrated control can begin quite soon, but large-scale substitution will depend on (h) integrated control research programme; naturally (h), (i) and (j) will run in parallel and are therefore represented as one; (g) will also continue for some time.

(4) diversified farming practices (k) and integrated control (j) will link up and form an agriculture best-suited for small, reasonably self-sufficient communities, so stimulating their development: significant feedback, therefore, will occur from this point.

(5) likely to be necessary at least until 2100.

(6) labour released from road building can go to (m) clearance of derelict land, which should be completed by 1985; thereafter there may be other renewal programmes such as canal restoration, while agriculture will increasingly require more manpower.

(7) development of alternative technologies (q) and redirecting of industry (r) will proceed in harness; progressively significant feedback between (b) and (t).

(8) target date for maximum redistribution of government 2030 to coincide with 45 years operation of (w); see note (9).

(9) five years only allowed for preliminary organisation and research, since it can proceed in harness with teacher training (v) and also with the education programme itself (w).

(10) an experimental community of 500 could be set up to clarify problems; feedback to (u).

(11) as soon as communities are small enough, domestic sewage can be returned to the land; there should be the firm beginnings of a good urban-rural mix by then.

(12) by this time there should be sufficient diversity of agriculture, decentralisation of industry and redistribution of government, together with a large proportion of people whose education is designed for life in the stable society, for the establishment of self-sufficient, self-regulating communities to be well-advanced. At this point taxation, grants, incentives, etc, could be taken over by the communities themselves. A further generation is allowed until target date, however.

A BLUEPRINT FOR SURVIVAL

The Goal

311. There is every reason to suppose that the stable society would provide us with satisfactions that would more than compensate for those which, with the passing of the industrial state, it will become increasingly necessary to forgo.

312. We have seen that man in our present society has been deprived of a satisfactory social environment. A society made up of decentralised, self-sufficient communities, in which people work near their homes, have the responsibility of governing themselves, of running their schools, hospitals, and welfare services, in fact of constituting real communities, should, we feel, be a much happier place.

313. Its members, in these conditions, would be likely to develop an identity of their own, which many of us have lost in the mass society we live in. They would tend, once more, to find an aim in life, develop a set of values, and take pride in their achievements as well as in those of their community.

314. It is the absence of just these things that is rendering our mass society ever less tolerable to us and in particular to our youth, and to which can be attributed the present rise in drug-addiction, alcoholism and delinquency, all of which are symptomatic of a social disease in which a society fails to furnish its members with their basic psychological requirements.

315. More than a hundred years ago, John Stuart Mill realised that industrial society, by its very nature, could not last for long and that the stable society that must replace it would be a far better place. He wrote[1]:

"I cannot . . . regard the stationary state of capital and wealth with the unaffected aversion so generally manifested towards it by political economists of the old school. I am inclined to believe that it would be, on the whole, a very considerable improvement on our present condition. I confess I am not charmed with the ideal of life held out by those who think that the normal state of human beings is that of struggling to get on; that the trampling, crushing, elbowing, and treading on each other's heels which forms the existing type of social life, are the most desirable lot of human kind. . . . The northern and middle states of America are a specimen of this stage of civilisation in very favourable circumstances; and all that these advantages seem to have yet done for them . . . is that the life of the whole of one sex is devoted to dollar hunting, and of the other to breeding dollar-hunters.

"I know not why it should be a matter of congratulation that persons who are already richer than anyone needs to be, should have doubled their means of consumings things which give little or no pleasure except as representative of wealth . . . It is only in the backward countries of the world that increased production is still an important object; in those most advanced, what is economically needed is a better distribution, of which one indispensable means is a stricter restraint on population . . . The density of population necessary to enable mankind to obtain, in the greatest degree, all the advantages both of cooperation and of social intercourse, has, in all the most populous countries, been attained . . . It is not good for a man to be kept perforce at all times in the presence of his species . . . Nor is there much satisfaction in contemplating a world with nothing left to the spontaneous activity of nature . . . If the earth must lose that great portion of its pleasantness which it owes to things that the unlimited increase of wealth and population would extirpate from it, for the mere purpose of enabling it to support a larger population, I sincerely hope, for the sake of posterity, that they will be content to be stationary, long before necessity compels them to it.

"It is scarcely necessary to remark that a stationary condition of capital and population implies no stationary state of human improvement. There would be as much scope as ever for all kinds of mental culture, and moral and social progress; as much room for improving the Art of Living and much more likelihood of it being improved, when minds cease to be engrossed by the art of getting on."

The importance of a varied environment

321. In our industrial society, the only things that tend to get done are those that are particularly conducive to economic growth, those in fact that, in terms of our present accounting system, are judged most efficient!

322. This appears to be almost the sole consideration determining the nature of the crops we sow, the style of our houses, and the shape of our cities. The result, among other things, is the dreariest possible uniformity.

323. In a stable society, on the other hand, there would be nothing to prevent many other considerations from determining what we cultivate or build. Diversity would thus tend to replace uniformity, a trend that would be accentuated by the diverging cultural patterns of our decentralised communities.

324. As Rene Dubos has pointed out[2]:

"In his recent book, *The Myth of the Machine*, Lewis Mumford states that 'If man had originally inhabited a world as blankly uniform as a "high-rise" housing development, as featureless as a parking lot, as destitute of life as an automated factory, it is doubtful that he would have had a sufficiently varied experience to retain images, mould language, or acquire ideas'. To this statement, Mr Mumford would probably be willing to add that, irrespective of genetic constitution, most young people raised in a featureless environment and limited to a narrow range of life experiences will be crippled intellectually and emotionally.

"We must shun uniformity of surroundings as much as absolute conformity of behaviour, and make instead a deliberate effort to create as many diversified environments as possible. This may result in some loss of efficiency, but the more important goal is to provide the many kinds of soil that will permit the germination of the seeds now dormant in man's nature. In so far as possible, the duplication of uniformity must yield to the organisation of diversity. Richness and variety of the physical and social environment constitute crucial aspects of functionalism, whether in the planning of cities, the design of dwellings, or the management of life."

Real Costs

331. We might regard with apprehension a situation in which we shall have to make do without many of the devices such as motor-cars, and various domestic appliances which, to an ever greater extent are shaping our everyday lives.

332. These devices may indeed provide us with much leisure and satisfaction, but few have considered at what cost. For instance, how many of us take into account the dull and tedious work that has to be done to manufacture them, or for that matter to earn the money required for their acquisition? It has been calculated[3] that the energy used by the machines that provide the average American housewife with her high standard of living is the equivalent of that provided by five hundred slaves.

333. In this respect, it is difficult to avoid drawing a comparison between ourselves and the Spartans, who in order to avoid the toil involved in tilling the fields and building and maintaining their homes employed a veritable army of helots. The Spartan's life, as everybody knows, was a misery. From early childhood, boys were made to live in barracks, were fed the most frugal and austere diet and spent most of their adult life in military training so as to be able to keep down a vast subject population, always ready to seize an opportunity to rise up against its masters. It never occurred to them that they would have been far better off without their slaves, fulfilling themselves the far less exacting task of tilling their own fields and building and maintaining their own homes.

334. In fact "economic cost", as we have seen, simply does not correspond to "real cost". Within a stable society this gap must be bridged as much as possible.

335. This means that we should be encouraged to buy things whose production involves the minimum environmental disruption and which will not give rise to all sorts of unexpected costs that would outweigh the benefits that their possession might provide.

Real Value

341. It is also true, as we have seen, that "economic value" as at present calculated does not correspond to real value any more than "economic cost" corresponds to real cost.

342. Our standard of living is calculated in terms of the market prices of the goods that it includes. These do not distinguish between, on the one hand, the gadgets that we do not really need and such essentials as unpolluted water, air and food on which our health must depend. In fact it tends to place greater value on the former, as we usually take the latter for granted.

343. It is in terms of these market prices that the GNP is calculated, and as we have seen, this provides the most misleading indication of our well-being.

Edward Mishan[4] points out that "... An increase in the numbers killed on the roads, an increase in the numbers dying from cancer, coronaries or nervous diseases, provides extra business for physicians and undertakers, and can contribute to raising GNP. A forest destroyed to produce the hundreds of tons of paper necessary for the American Sunday editions is a component of GNP. The spreading of concrete over acres of once beautiful countryside adds to the value of GNP ... and so one could go on."

344. In the same way, many of the machines whose possession is said to increase our standard of living are simply necessary to replace natural benefits of which we have been deprived by demographic and economic growth. We have pointed out how true this is of the ubiquitous motor-car. Also, many labour-saving devices are now necessary because with the disintegration of the extended family there is no one about to do the household chores. The fact that both husband and wife must, in many cases, go out to work to earn the money to buy the machines required to do these chores can serve only to render such devices that much more necessary.

345. In a stable society, everything would be done to reduce the discrepancy between economic value and real value, and if we could repair some of the damage we have done to our physical and social environment, and live a more natural life, there would be less need for the consumer products that we spend so much money on. Instead we could spend it on things that truly enrich and embellish our lives.

346. In manufacturing processes, the accent would be on quality rather than quantity, which means that skill and craftsmanship, which we have for so long systematically discouraged, would once more play a part in our lives. For example, the art of cooking would come back into its own, no longer regarded as a form of drudgery, but correctly valued as an art worthy of occupying our time, energy and imagination. Food would become more varied and interesting and its consumption would become more of a ritual and less a utilitarian function.

The arts would flourish: literature, music, painting, sculpture and architecture would play an ever greater part in our lives, while achievements in these fields would earn both money and prestige.

347. A society devoted to achievements of this sort would be an infinitely more agreeable place than is our present one, geared as it is to the mass produc-

tion of shoddy utilitarian consumer goods in ever greater quantities. Surprising as it may seem to one reared on today's economic doctrines, it would also be the one most likely to satisfy our basic biological requirements for food, air and water, and even more surprisingly, provide us with the jobs that in our unstable industrial society are constantly being menaced.

348. Indeed, as we have seen, the principal limitation to the availability of jobs today is the inordinately high capital outlay required to finance each worker. This limitation is withdrawn as soon as we accept that, within the framework of an overall reorganisation of our society, it would be possible for capital outlay to be reduced without reducing our real standard of living.

349. One of the Bishop of Kingston's ten commandments[5] is: "You shall not take the name of the Lord thy God in vain by calling on his name but ignoring his natural law." In other words, there must be a fusion between our religion and the rest of our culture, since there is no valid distinction between the laws of God and Nature, and Man must live by them no less than any other creature. Such a belief must be central to the philosophy of the stable society, and must permeate all our thinking. Indeed it is the only one which is properly scientific, and science must address itself much more vigorously to the problems of co-operating with the rest of Nature, rather than seeking to control it.

350. This does not mean that science must in any way be discouraged. On the contrary, within a stable society, there would be considerable scope for the energies and talents of scientist and technologist.

Basic scientific research, plus a good deal of multidisciplinary synthesis, would be required to understand the complex mechanisms of our ecosphere with which we must learn to co-operate.

351. There would be a great demand for scientists and technologists capable of devising the technological infrastructure of a decentralised society. Indeed, with the application of a new set of criteria for judging the economic viability of technological devices, there must open a whole new field of research and development.

352. The recycling industry which must expand very considerably would offer innumerable opportunities, while in agriculture there would be an even greater demand for ecologists, botanists, entomologists, mycologists etc., who would be called upon to devise ever subtler methods for ensuring the fertility of the soil and for controlling "pest" populations.

353. Thus in many ways, the stable society, with its diversity of physical and social environments, would provide considerable scope for human skill and ingenuity.

354. Indeed, if we are capable of ensuring a relatively smooth transition to it, we can be optimistic about providing our children with a way of life psychologically, intellectually and aesthetically more satisfying than the present one. And we can be confident that it will be sustainable as ours cannot be, so that the legacy of despair we are about to leave them may at the last minute be changed to one of hope.

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A BLUEPRINT FOR SURVIVAL

The Movement for Survival (MS)

1. Aim

We need a Movement for Survival, whose aim would be to influence governments, and in particular that of Britain, into taking those measures most likely to lead to the stabilisation and hence the survival of our society.

2. Structure

We envisage it as a coalition of organisations concerned with environmental issues, each of which would remain autonomous but which saw the best way of achieving its aims was within the general framework of the *Blueprint for Survival.*

The organisations have already expressed general support for the *Blueprint:*

The Conservation Society
Friends of the Earth
The Henry Doubleday Research Association
The Soil Association
Survival International

Two representatives of each member organisation would join the Action Committee of the MS, which would elect a chairman and secretary to run the day-to-day business of the Movement.

3. Individual membership

Members of constituent organisations would automatically become members of the MS. Individuals who belonged to none of these bodies could join the MS only through one of these organisations.

Regular news of MS activities would be published in *The Ecologist*, a subscription to which would be available to MS members at the reduced price of £3 p.a. (25 per cent reduction). Representatives of the constituent organisations could become members of *The Ecologist's* editorial board.

4. Further information

Organisations wishing to join the MS and all others seeking further information should write to the Acting Secretary, The Movement for Survival, c/o *The Ecologist*, Kew Green, Richmond, Surrey.

A BLUEPRINT FOR SURVIVAL

APPENDIX A

Ecosystems and their disruption

It is necessary to survey the essential features of the environment in order to understand how it is being affected by man's activities.

We can define the environment as a system which includes all living things and the air, water and soil which is their habitat. This system is often referred to as the ecosphere. To describe it as a system is to accentuate its unity; a system being something made up of interrelated parts in dynamic interaction with each other, and capable for certain purposes, of co-operating in a common behavioural programme.

Such a programme must be regarded as goal-directed, and its goal the maintenance of stability. This appears to be the basic goal of all the self-regulating behavioural processes that make up the ecosphere.

Stability is best defined as a system's ability to maintain its basic features—in other words to survive in the face of environmental change. This means that, in a stable system, change will be minimised and will occur only as is necessary to ensure adaptation to a changing environment. In other words, as stability increases so the frequency of random changes will be correspondingly reduced.

It is easy to see how the ecosphere during the last few thousand million years of evolution has slowly become more stable.

Whereas the deserts, which once covered our planet, reflected the environmental pressures to which they were subjected, the forests that developed to replace them have a capacity to maintain a relatively stable situation in the face of internal and external change. For instance, they ensure an optimum balance between the oxygen and carbon dioxide contents of the air by emitting one and absorbing the other. They provide good conditions for the run-off to rivers to be regulated. They periodically shed their leaves which build up humus, and hence ensure the continued fertility of the soil. They provide a relatively constant ambient temperature to the wild animals that live within their shade, who, as they evolve also develop stabilising mechanisms ensuring the stability of what is sometimes called their "internal environment"; the constant body temperature of warm blooded mammals being an obvious example.

Perhaps the most important feature of the ecosphere is its degree of organisation. It is made up of countless ecosystems, themselves organised into smaller ones, which are further organised into still smaller ones. Each of these is made up of populations of different species in close interaction with each other, some of which are usually organised into communities and families—further organised into cells, molecules and atoms etc.

The opposite of organisation is randomness or, what is often referred to as entropy. In fact it can be said that the ecosphere differs from the surface of the moon and probably from that of all the other planets in our solar system, in that randomness, or entropy, have been progressively reduced and organisation, or negative entropy, have been correspondingly increased. According to the second law of thermodynamics, there is a tendency in all systems towards increasing randomness, or entropy. This must be so, since to move in this direction is to take the line of least resistance and also because whenever energy is converted (and this must occur during all behavioural processes), waste, or random parts must be generated—from oxidation and friction if from nothing else.

The ecosphere has succeeded in counteracting this tendency by virtue of several unique features and because it is an open system from the point of view of energy, being continually bombarded with solar radiation.

This radiation is used by green plants during photosynthesis to organise nutrients in the soil into complex plant tissue, which are then eaten by herbivores, and hence reorganised into still more complex animal tissue.

In such processes waste or random parts must be generated. However, so long as the corresponding reduction in organisation is less than the increase in organisation achieved during the process, then entropy will have been reduced. Such increases will be limited by all sorts of factors including the availability of energy and materials, the environment's capacity to absorb waste and the organisational capacity of the system. Waste must therefore be kept down to a minimum. This can only be done by recycling it so as to ensure that the waste generated by one process serves as the materials for the next. This is essential for another reason:

Whereas the ecosphere is an open system as regards energy, it is a closed one as regards materials, which is another reason why all materials must be recycled, and why the waste products of one process must serve as materials for the next.

Also some of the more highly organised materials required for sophisticated processes have taken hundreds of millions of years to develop in the case of fossil fuels, for instance, and thousands of millions of years in the case of the herbivorous animals required as food by carnivores. It is thus clear that to avoid increasing entropy, they cannot be used up faster than they are produced. Hence the essential cyclic nature of all ecological processes and the absolute necessity for recycling everything.

It is possible to trace just how all the resources, such as carbon, nitrogen, phosphorus, water, etc., made use of in behavioural processes, are recycled. The food cycle is particularly illustrative. Take the case of a marine ecosystem: fish excrete organic waste which is converted by bacteria to inorganic products. These provide nutrients, permitting the growth of algae which are eaten by fish, and the cycle is complete. In this way the wastes are eliminated, the water kept pure, and, at the same time, the materials for the next stage of the process are made available.

One of the most important features of life processes is that they are automatic or self-regulating. Self regulation can only be ensured in one way: data must be detected by the system, transducted into the appropriate informational medium, and organised so as to constitute a model or "template" of its relationship with its environment. Whenever this relationship is modified in such a way that it deviates from the

optimum, the model is correspondingly affected, and it can be used to guide the appropriate course of action, and monitor each new move, until a new position of equilibrium has been reached. This basic cybernetic model explains how all systems, regardless of their level of complexity, adapt to their respective environments. The fact that all the parts of the ecosphere are linked to each other in this way ensures that a general readjustment of the most subtle nature can occur to restore its basic structure after any disturbance.

To suppose that we can ensure the functioning of the ecosphere ourselves with the sole aid of technological devices thereby dispensing with the elaborate set of self-regulating mechanisms that has taken thousands of millions of years to evolve, is an absurd piece of anthropocentric presumption that belongs to the realm of pure fantasy.

It may be possible to replace certain natural controls locally and for a short while without any serious cataclysm occurring, but if we push things too far, if for instance the insecticides we use to replace the self-regulating controls that normally ensure the stability of insect populations were to destroy nitrogen-fixing bacteria or pollinating insects, all the money and all the technology in the world would not suffice to replace them and thereby to prevent life processes from grinding to a halt. Yet this substitution is implicit in the aim of industrial society.

As this aim is progressively realised, and as we become more and more dependent on technological devices, i.e. external controls, so must there be a corresponding increase in the instability of our social system and hence in our vulnerability to change. Imagine, what it will be like when water supplies have been exhausted and we are dependent upon desalination plants for our drinking water, when traditional methods of agriculture have totally given way to ever more ingenious forms of factory farming, and when the natural mechanisms providing us with the air we breathe have been so completely disrupted that vast installations are needed to pump oxygen into the atmosphere and filter out the noxious gasses emitted by our industrial installations.

Clearly under such conditions, the slightest technical hitch or industrial dispute, or shortage of some key resource, might be sufficient to deprive us of such basic necessities of life as water, food and air—and bring life to a halt.

If man wishes to survive, to ensure the proper functioning of the self-regulating mechanisms of the ecosphere must be his most basic endeavour. For this to be possible however the latter's essential structure must be respected. Deviations may be possible but only within acceptable limits.

One way of exceeding these limits is to supply the system with more waste than can be used to provide the materials for other processes. In such conditions the system is said to be "overloaded"; the self-regulating mechanisms can no longer function and the waste simply accumulates. In other words entropy, or randomness, has increased and the surface of the earth resembles that much more that of the moon.

Thus, to return to our marine ecosystem, if the cycle is overloaded with too much sewage, detergents or artificial fertilisers which are nutrients to aquatic plant life, the amount of oxygen required to ensure the decomposition of these substances by the appropriate bacteria may be so high that other organisms will be deprived of an adequate supply.

If this goes on long enough the oxygen level will be reduced to zero. Without oxygen, the bacteria will die and a crucial phase in the cycle will have been interrupted, thereby bringing it rapidly to a halt. As a result, what was once an elaborate ecosystem, supporting countless forms of life in close interaction with each other now becomes a random arrangement of waste matter.

Needless to say the cycle will also come to a halt if, on the contrary, there were a shortage of nutrients. In such conditions the algae could not survive, and the fish population deprived of its sustenance, would rapidly die off.

This illustrates an essential principle of organisation; there must be an optimum value to every variable in terms of which the system is described. When each variable has its correct value, then the system described can be regarded as having its correct structure. This means that there is no value that can be increased or reduced indefinitely without bringing about the system's eventual breakdown.

To cherish the illusion that the population and affluence of human social systems are exceptions to this law, is, as we shall see, to court the gravest possible calamities.

In order to maintain the system's structure, the actions of the self-regulating sub-systems not only seek to establish a stable relationship with another sub-system, but with their environment as a whole. In other words, they do not aim at satisfying a specific requirement, but at achieving a compromise between a whole set of often competing requirements; that which best satisfies the requirements of the environment as a whole.

Technological devices, of course, do precisely the opposite. They are geared to the achievement of specific short-term targets, regardless of environmental consequences. Since many requirements must be satisfied to maintain stability, such devices by their very nature must cause environmental problems, and, as a result, they must inevitably tend towards achieving equilibrium positions which display lower rather than higher stability. This means that the probability that disequilibria will occur and their degrees of seriousness are both likely to increase as must the rate at which new devices will be required as well as the effectiveness required of them.

In other words, the role played by technology must increase by positive feedback and our society must become even more addicted to it.

In these circumstances, unless technological innovation can proceed indefinitely at an exponential rate, then it is only a question of time before a disequilibrium occurs for which there is no technological solution, which must spell the complete breakdown of the system.

Industrial society, when it reaches a certain stage of development, begins to affect its environment in yet another manner; it devises, and becomes correspondingly dependent upon, synthetic products of different sorts to replace ever-scarcer natural products. Thus plastics are developed to replace wood products; detergents to replace soaps made from natural fats, synthetic fibres to replace natural fibres; chemical fertilisers to replace organic manure. At the same time, nuclear energy slowly replaces that previously derived from fossil fuels.

It is probable that our ecosphere does not produce a single molecule for which there is not an enzyme capable of

breaking it down, in order to perpetuate the essential cycle of life, growth, death and decay. This is not so with synthetic products. They cannot normally be broken down in this way—save in some cases by human manipulation, which is only practicable on a small scale and in specific conditions. It is thus no longer a question of overloading a system. Even the slightest amount of these products, when introduced into our ecosphere, constitutes pollution, while since by their very nature they must continue accumulating, to produce them methodically is to ensure the systematic replacement of the ecosphere with extraneous waste matter.

What is worse, many of these substances find their way into life processes with which they can seriously interfere. Thus strontium 90 gets into the bones of growing children and can give rise to bone cancer; Iodine 131 accumulates in the thyroid gland and can give rise to cancer of the thyroid; DDT accumulates in the fatty matter and in the liver and may cause cancer and other liver diseases; plastics and many other pollutants also accumulate in the liver and kidneys, etc.

It is not surprising that as industrialisation proceeds, so there is a very rapid increase in the so-called degenerative diseases. Carcinogenic agents also tend to be mutagens, and their proliferation must mean a gradual reduction in the adaptiveness of our species, a process that clearly cannot go on indefinitely[2].

There is another way in which we are degrading the ecosphere. One of its most important features is its complexity. The greater the number of different plant and animal species that make up an ecosystem, the more likely it is to be stable. This is so because, as Elton points out, in such a system every ecological niche is filled. That is to say, every possible differentiated function for which there is a demand within the system is in fact fulfilled by a species that is specialised in fulfilling it. In this way it is extremely difficult for an ecological invasion to occur, i.e. for a species foreign to the system entering and establishing itself, or, worse still, proliferating and destroying the system's basic structure.

It also means that no species forming part of the system is likely to be able to expand beyond its optimum size. The availability and size of an ecological niche undoubtedly constitutes an effective population control. Thus the diet of a specialised member of a highly differentiated ecosystem will itself be of a specialised nature, which means that if the population of a particular species were to increase, or, alternatively, to decrease, the food supply of the other species would not be affected. The opposite would be the case with species that normally form part of a simple ecosystem.

Thus goats are adapted to live in mountain areas, where ecological complexity is low, and in order to survive they have to be able to eat almost anything. The result is when they are brought down to the plains, they make short shrift of its vegetation, and their proliferation compromises the food supply of many other species.

As industrial man destroys the last wildernesses, as herds of domesticated animals replace inter-related animal species, and vast expanses of crop monoculture supplant complex plant ecosystems, so complexity and hence stability are correspondingly reduced.

Industrial man is also reducing complexity in other ways. For instance, economic pressures force farmers to reduce the number of different strains of crops under cultivation. Only those that present short-term economic advantages tend to survive. This process has been accentuated with the so-called "green revolution". Special high yield strains of rice and wheat that respond particularly well to artificial fertilisers have been developed and introduced on a large scale in many parts of the third world. In these areas many other strains have been abandoned. In this way we are reducing complexity, in some cases irreversibly, and if anything should happen to the surviving strains, essential crops like wheat and rice could well be jeopardised.

We are reducing complexity in still another way. The greater the number of trophic levels (in other words the greater the length of food chains), the more stable is an ecosystem likely to be. Thus the simplest marine ecosystem would consist of phytoplankton, capable of harnessing the sun's energy and micro-organisms capable of decomposing them. By introducing zooplankton into the system, another link has been introduced into the food chain. These, by preying on the phytoplankton, keep down their numbers and weed out the weak and unadaptive. In this way, they exert both quantitative and qualitative controls, and exert an important stabilising influence. If fish are then introduced to feed on the zooplankton, the system becomes correspondingly more stable.

Needless to say, man's activities are everywhere leading to a reduction in the length of food chains. The larger terrestrial predators have been virtually eliminated in industrial countries, and this process is now taking place in the seas. Man, by refusing to tolerate competitors for his food supply, is ultimately jeopardising the stability of this food supply, and hence, its very availability.

Also, as SCEP points out, environmental stress appears to affect predators more radically than herbivores. In aquatic systems the top-level predators, which eat other predators, are the most sensitive of all. This appears to be the case with such disruptive situations as oxygen deficiency, thermal stress, and the introduction of toxic materials such as pesticides and fertilisers.

The effect must be to reduce the number of trophic levels in any ecosystem thereby increasing its instability. SCEP cites several examples:

"Overenrichment by sewage waste and fertiliser runoff of freshwaters, or pollution with industrial wastes, leads to the rapid loss of trout, salmon, pike, and bass. Spraying crops for insect pests has inadvertently killed off many predaceous mites, resulting in outbreaks of herbivorous mites that obviously suffered less. Forest spraying has similarly 'released' populations of scale insects after heavy damage to their wasp enemies."

In addition, SCEP points out that "such fat-soluble pesticides as DDT are concentrated as they pass from one feeding level to the next. In the course of digestion a predator retains rather than eliminates the DDT content of its prey. The more it eats, the more DDT it accumulates. The process results in especially high concentrations of toxins in predaceous terrestrial vertebrates."

Predators also suffer from the destruction of their food supply. Severe damage to the lower levels in the food chain usually leads to the extinction of the predator before that of the species on which it preys.

There is yet another way in which we are reducing complexity. Populations at any given moment will be made up of individuals of every possible age group. We tend to replace such balanced populations with plantations of trees

and other crops which are all of the same age and are particularly vulnerable to diseases affecting them at particular stages in their life cycle. This principle must apply equally well to intensive stock rearing units and especially factory farms. Once more the result is to reduce stability.

Technological devices must also reduce complexity. They constitute external controls exerted by precarious human manipulation. They invariably replace natural controls of a far more complex nature.

Thus, to replace the natural controls which ensure the stability of an insect population by a single chemical pesticide involves a drastic reduction in complexity. The same must be true when we replace the natural mechanisms ensuring soil fertility with nitrogen, phosphorus and potassium which are the main ingredients of artificial fertilisers.

In fact, most human activities are reducing the stability of the ecosphere, which is simply another way of saying that they are determining its systematic degradation.

For several thousand million years, the ecosphere has been developing into an extremely complex organisation of different forms of life in close interaction with each other. In doing this it has been counteracting the basic tendency of all systems towards randomness or entropy. The elaborate mechanisms that have enabled the ecosphere to develop in this manner have been disrupted by man's activities. In his gross presumption, he has sought to replace them with devices causing dereliction and confusion, which rather than seek to satisfy the countless competing requirements of the ecosphere, have been geared to the satisfaction of petty, short-term anthropocentric ends. As a result, the organisational process has been reversed; waste, or random parts, are accumulating faster than organisation is building up. Rather than counteract the inexorable trend towards entropy, industrial man's activities are accelerating it.

If these activities continue to increase exponentially at 6.5 per cent per annum, or double every 13½ years, it cannot take many decades before our planet becomes incapable of supporting complex forms of life.

Pollution

Studies of the effects of pollutants on ecosystems have often yielded contradictory results. Rather than attempt to weigh these up, we have chosen to summarise some of the findings of what is almost certainly the most authoritative study, that undertaken in 1969 by an impressive group of scientists from many different disciplines under the auspices of MIT and referred to as "The Study of Critical Environmental Problems" or SCEP. This study is to be used as background material for the UN Conference on the Human Environment 1972.

SCEP accentuates the necessity for adopting a holistic approach. "The significant aspect of human action is man's total impact on ecological systems, not the particular contributions that arise from specific pollutants. Interaction among pollutants is more often present than absent. Furthermore, the total effect of a large number of minor pollutants may be as great as that of one major pollutant. Thus, the total pollution burden may be impossible to estimate except by direct observation of its overall effect on ecosystems."

The scale of human activity can be estimated by comparing specific man-induced processes with the natural rates of geological and ecological processes. It can be shown that in at least 12 cases man-induced rates are as large or larger than the natural rates (see Table 5).

It is pointed out that with a five per cent natural growth increment in the mining industries, this will apply to many more materials.

"... these comparisons show that at least some of our actions are large enough to alter the distribution of materials in the biosphere. Whether these changes are problems depends upon the toxicity of the material, its distribution in space and time, and its persistence in ecological terms."

Most of the disruptive processes already described are well advanced, however, and as they occur slowly the most visible effect is a gradual deterioration of ecosystems, "characterised by instability and species loss".

Many lakes and urban centres have severely deteriorated ecosystems. Less severe deteriorations occur more commonly, often as temporary afflictions in ecosystems that otherwise manage to survive intact: ... This general problem is labelled "attrition" because it lacks discrete steps of change. Stability is lost more and more frequently, noxious organisms become more common, and the aesthetic aspects of waters and countryside become less pleasing. This process has already occurred many times in local areas. If it were to happen gradually on a global scale, it might be much less noticeable, since there would be no surrounding ecosystems against which to measure such slow changes. Each succeeding generation would accept the status quo as "natural".

Energy products

Present and future levels of energy consumption are particularly relevant to estimating our capacity to disrupt ecosystems. The best available calculation appears to be that made by the Battelle Memorial Institute in 1969. In 1968 energy consumption in the US was slightly over 60,000 trillion BTU. It appears to be rising at 3.2 per cent per annum and is expected to be 170,000 trillion BTUs by the year 2000.

Over the last 50 years there has been a decreasing amount of energy used for each unit of GNP. The increased technical efficiency of energy used has tended to more than offset the more intense use of energy. The trend, however, appears to be changing. The present policy is to encourage energy use while the technical efficiency of new electric power plants and other energy conversion devices is no longer increasing and may even decrease over the next decades. If this is so, then it is possible that this and other projections have underrated future energy requirements. On the other hand conservation pressures might lead to a reduced usage and this has not been taken into account.

World wide energy consumption projection made by Joel Darmstadter of Resources for the Future has appeared in a work *Energy and the World Economy* (see Table 1).

What are likely to be the emissions from power production and other forms of energy production?

It is estimated that in 1967 some 13.4 billion metric tons of CO_2 were released from fossil fuel combustion and that emissions in 1980 (using Darmstadter's projection) would be 26 billion metric tons for the world as a whole.

SCEP points out that the trend towards depleting the remaining stands of original forests, such as those in tropical Brazil, Indonesia and the Congo, will further reduce the capacity of the ecosphere to absorb Co_2 and may

release even more Co_2 to the atmosphere. The Co_2 content of the atmosphere is increasing at a rate of 0.2 per cent per year since 1958. One can project, on the basis of these trends, an 18 per cent increase by the year 2000, i.e. from 320 ppmm to 379 ppmm. SCEP considers that this might increase temperature of the earth by 0.5°C. A doubling of Co_2 might increase mean annual surface temperatures by 2°C (see Table 3).

Heat

Thermal waste energy is increasing at a rate of 5.7 per cent per annum, which means that it is likely to increase by a factor of 6 before the end of the century. The total for 1970 was 5.5 10^6 MW which is likely to increase to 9.6 by 1980 and 31.8 10^6 MW by 2000. The effects on global climate are not known.

Emissions of pollutants such as sulphur oxides, nitrogen oxides, hydrocarbons, carbon monoxide and particulate matter, cannot be predicted with any assurance. The theoretical knowledge necessary to make these predictions does not yet exist nor are the relevant facts available.

As far as emissions of radionuclides are concerned the major source will be at the site of fuel reprocessing plants. One estimate is that 99.9 per cent of all such emissions entering the environment are from such sources. Concern is expressed for emissions of "potentially hazardous" radionuclides such as iodine 131, xenon 153, strontium 90, and caesium 137. Possible releases of tritium (hydrogen 3) and krypton 85 are also of concern.

Total emissions would not lead to anything like maximum permissible concentrations (MPC) if dispersal was assured. However, one must take into account the tendency of radionuclides to concentrate in certain organisms and to get into food chains. Concentration factors of 1,000 for caesium in the flesh of bass have been found, of 8,700 in the bones of the blue gills, of 350,000 for radioactivity content in caddis fly larvae, 40,000 for duck egg yolks and 75,000 for adult swallows. Table 7 shows estimated concentration factors for some radionuclides in aquatic organisms.

Phytoplankton also tend to concentrate activation products such as zinc 65, cobalt 67, iron 55 and manganese 54 to an even greater extent than fission products.

When breeder reactors are introduced plutonium emissions will also become a concern.

The management of concentrated and highly radioactive wastes is a serious problem deserving far more study. Table 2 provides an estimate of accumulated wastes for 1970, 1980 and 2000.

Domestic and agricultural wastes

Dredged wastes from urban areas contain sediment, sewage solids, agricultural and industrial wastes. These also tend to be deposited in rivers or coastal waters. The total amount deposited in this way is estimated at between 150 and 220 million metric tons per years, and appears to be increasing at 4 per cent per annum.

World production and consumption of chemical fertilisers (except during periods 1914-18 and 1940-45) have doubled or tripled in each decade. Total world use in 1963-64 exceeded 33 million metric tons, only 10 per cent of which were used in developing countries. Their share, however, is increasing rapidly.

Present annual world production of pesticides is probably about 1 million metric tons. It is likely to go on increasing in view of the increasing world food shortage and because of diminishing returns on their use. Thus to double world food production which as we have seen is likely to be necessary, it will be necessary to increase consumption by no less than six times (see Table 12).

In the industrialised countries there is likely to be a move away from DDT to less persistent but more toxic pesticides such as phorate, dimiton, parathion, etc. These require more frequent sprayings to make up for their reduced persistence. It is unlikely that the developing countries will be able to afford them, so consumption of DDT is likely to continue growing.

SCEP points out the way in which agriculture becomes increasingly dependent on the use of these poisons: "Realisation that the use of pesticides increases the need to continue their use is not new, nor is the awareness that the constant use of pesticides creates new pests. For many of our crops on which pesticide use is heavy, the number of pests requiring control increases through time. In a very real sense, new herbivorous insects find shelter among

Table 1

Darmstadter's Projection of World Energy Consumption in 1980

		Solid		Liquid		Gas		Hydro†		Nuclear†		Overall	
	A*	10^{12} kWh(t)‡	Percentage of World Consumption	10^{12} kWh(t)‡	Percentage of World Consumption	10^{12} kWh(t)‡	Percentage of World Consumption	10^{12} kWh(t)‡	Percentage of World Consumption	10^{12} kWh(t)‡	Percentage of World Consumption	10^{12} kWh(t)‡	Percentage of World Consumption
Developed Countries													
United States	3 5	5 0	17 3	9 4	25 3	8 3	41 9	0 34	18 1	0 98	52.0	24 0	26 8
Canada	5.5	0 3	0 9	1 2	3.2	1.0	4 8	0 22	11 6	0 05	2 8	2 8	3.0
Western Europe	4 0	2 7	9 4	9 2	24 9	2 1	10 3	0 46	24 1	0 63	33.5	15 1	16 8
Communist Eastern Europe	4 6	3 6	12 5	1 5	3.9	0 7	3.5	0 02	1 2	0 04	2.1	5.9	6 6
USSR	6 5	5.7	19 7	5 2	14.0	5.9	29.8	0 29	15.3	0 04	2.1	17.1	19.1
Japan	7 9	0 5	1 9	3 5	9 5	0 1	0 4	0.11	5.7	0 11	5 6	4 3	4.9
Oceania	4 8	0 4	1 3	0 4	1 2	0 1	0 7	0.04	2.1	0 01	0 3	1 0	1.1
Total	4 7	18.2	63 0	30 4	82 0	18 2	91 4	1 48	78.1	1.86	98.4	70.2	78.3
Developing Countries													
Communist Asia	7 6	7 3	25 4	0.7	2 0	—	–§	0 04	2.2	0 01	0 4	8.1	9 1
Other Asia (exc. Japan)	8 5	2 3	3.1	2 4	6.5	0 4	2.2	0.14	7.3	0.02	1.0	5 2	5.8
Africa	6 5	0 9	0 6	0 7	1.9	0.2	0 9	0 06	3.0	—	—	1 8	2.0
Other America	7 4	0 2	7 9	2 8	7 6	1 1	5.5	0.18	9.4	0 00	0.2	4.3	4 8
Total	7 7	10 7	37.0	6.6	18 0	1.7	8 6	0 42	21.9	0 03	1.6	19.4	21.7
World Total	5 2	28 9	100 0	37.0	100 0	19.9	100 0	1 90	100.0	1.89	100 0	89 6	100.0

Source Estimated by Joel Darmstadter in *Energy and the World Economy* (to be published by The Johns Hopkins Press for Resources for the Future, Inc)

* Column A contains the projected average annual percentage of growth in energy consumption for 1965–1980

† Darmstadter follows the UN system of evaluating hydro and nuclear electricity This means that he used for *both* nuclear and hydropower the system used by the Group *only* for hydropower Darmstadter's actual figures were in metric tons of coal equivalent and were converted to kWh (both thermal and electrical in this case) at the UN rate of 1,000 kWh per 0 125 m t c e (for the factor see UN *World Energy Supplies* or the Appendix of any recent UN *Statistical Yearbook*).

‡ Converted from metric tons coal equivalent by using 27 3 × 10^6 Btu/m t c e and 0 293 × 10^{-3} kWh(t)/Btu.

§ Unknown, but believed to be small

our crops where their predator enemies cannot survive. Fifty years ago most insect pests were exotic species, accidently imported to a country lacking their natural enemies. More recently many of the pests, including especially the mites, leaf-rolling insects, and a variety of aphids and scale insects, have been indigenous. Thus pesticides not only create the demand for future use (addiction), they also create the demand to use more pesticide more often (habituation). Our agricultural system is already heavily locked into this process, and it is now spreading to the developing countries. It is also spreading into forest management. Pesticides are becoming increasingly 'necessary' in more and more places. Before the entire biosphere is 'hooked' on pesticides, an alternative means of coping with pests should be developed."

Of all pesticides, DDT is the most commonly used, and is now present in the fatty tissue of animals in every part of the world. Its effects are well documented. SCEP summarises some of the implications:

"The oceans are an ultimate accumulation site of DDT and its residues. As much as 25 per cent of the DDT compounds produced to date may have been transferred to the sea. The amount in the marine biota is estimated to be in the order of less than 0.1 per cent of total production and has already produced a demonstrable impact upon the marine environment.

"Population of fish-eating birds have experienced reproductive failures and population declines, and with continued accumulation of DDT and its residues in the marine ecosystem additional species will be threatened. The decline in productivity of marine food fish and the accumulation of levels of DDT in their tissues can only be accelerated by DDT's continued release to the environment.

"Certain risks in the utilisation of DDT are especially difficult to quantify, but they require most serious consideration. The rate at which it degrades to harmless products in the marine system is unknown. For some of its degradation products, half-lives are certainly of the order of years, perhaps even of decades. If most of the remaining DDT residues are presently in reservoirs which will in time transfer their contents to the sea, we may expect, quite independent of future manufacturing practices, an increased level of these substances in marine organisms. And if, in fact, these compounds degrade with half-lives of decades, there may be no opportunity to redress the consequences. The more the problems are studied, the more unexpected effects are identified. In view of the findings of the past decade, our prediction of the hazards may be vastly underestimated."

Heavy Metals

Pollution by heavy metals also gives cause for concern. "Some heavy metals are highly toxic to plants and animals including man. They are highly persistent and retain their toxicity for very long periods of time. Some have been used extensively as pesticides and have been dispersed into the environment as pesticides, as uncontrolled industrial wastes and emissions and other means." Much enters natural water systems through sewage discharges and only a portion is removed by normal sewage treatment.

Those heavy metals that are most toxic, persistent and abundant in the environment have been selected by SCEP for special review. These include mercury (Hg), lead (Pb), arsenic (As), cadmium (Cd), chromium (Cr), and nickel (Ni). Most heavy metals are

Tabl 2

Radioactive Wastes as a Function of Expanding US Nuclear Power

	Calendar Year		
	1970	1980	2000
Installed nuclear capacity, MW(e)	11,000	95,000	734,000
Volume high-level liquid waste[a,b]			
Annual production, gal/yr	23,000	510,000	3,400,000
Accumulated volume, gal[c]	45,000	2,400,000	39,000,000
Accumulated fission products, megacuries[b]			
Sr^{90}	15	750	10,800
Kr^{85}	1.2	90	1,160
H^3	0.04	3	36
Total for all fission products	1,200	44,000	860,000
Accumulated fission products, tons	16	388	5,350

Source: Snow, 1967 (reproduced from SCEP).
[a] Based on 100 gallons of high-level acid waste per 10,000 thermal megawatt days (MWd) irradiation.
[b] Assumes 3-yr lag between dates of power generation and waste production.
[c] Assumes wastes all accumulated as liquids.

Table 3

CO_2 Produced by Fossil Fuel Combustion, 1950-1967
(Billions of metric tons) (reproduced from SCEP)

Year	Coal	Lignite	Refined Oil Fuels	Natural Gas	Total
1950	3.7	0.9	1.4	0.4	6.4
1951	3.8	0.9	1.7	0.5	6.9
1952	3.8	0.9	1.8	0.5	7.0
1953	3.8	0.9	1.9	0.5	7.1
1954	3.8	0.9	2.0	0.6	7.3
1955	4.1	1.0	2.2	0.6	7.9
1956	4.4	1.1	2.4	0.7	8.6
1957	4.5	1.3	2.5	0.7	9.0
1958	4.6	1.4	2.6	0.8	9.4
1959	4.8	1.4	2.8	0.9	9.9
1960	5.0	1.4	3.1	1.0	10.5
1961	4.5	1.5	3.3	1.0	10.3
1962	4.6	1.5	3.5	1.1	10.7
1963	4.8	1.6	3.8	1.2	11.4
1964	5.0	1.7	4.2	1.3	12.2
1965	5.0	1.7	4.5	1.5	12.7
1966	5.1	1.7	4.8	1.6	13.2
1967	4.8	1.7	5.2	1.7	13.4
1980 (est)	11.1		10.8	4.0	26.0

biologically accumulated in the bodies of organisms, remain for long periods of time, and function as cumulative poisons. Table 4 indicates world production of these metals between the years 1963 and 1968 and illustrates the rate at which it is increasing.

It may be worth looking more closely at the problem of mercury pollution which is particularly topical.

SCEP quotes Stockinger: "Elemental mercury and most compounds of mercury are protoplasmic poisons and therefore may be lethal to all forms of living matter. In general, the organic mercury compounds are more toxic than mercury vapour or the inorganic compounds. Even small amounts of mercury vapour or many mercury compounds can produce mercury intoxication when inhaled by man. Acute mercury poisoning, which can be fatal or cause permanent damage to the nervous system, has resulted from inhalation of 1,200 to 8,500 micrograms per cubic meter of mercury. The more common chronic poisoning (mercurialism) which also affects the nervous system is an insidious form in which the patient may exhibit no well-defined symptoms for months or sometimes years after exposure".

Mercury is also dangerous when ingested in food. In Japan 111 cases of mercury poisoning occurred (with 44 deaths) a result of eating fish taken from Minamata Bay. Another outbreak occurred at Big Niigata City with 26 cases (and five deaths).

Mercury's toxicity is permanent. In addition when fish, shellfish, birds or mammals containing mercury are eaten by other animals the mercury may be absorbed and accumulated.

Industrial wastes and agricultural pesticides have caused severe mercury contamination in waters in Japan, Sweden and the US. Its use is increasing throughout the world and it "threatens to become critical in the world environment". Moreover, as SCEP points out mercury is but one of approximately 2 dozen metals that are highly toxic to plants and animals.

Oil pollution

We tend to regard oil pollution of the seas as caused principally by accidental spills like that of the Torrey Canyon. Such accidents cause the most evident damage, "but they make up less than 10 per cent of the estimated 2.1 million metric tons of oil that man introduces directly into the world's waters. At least 90 per cent originates in the normal operations of tankers, other ships, refineries, petro-chemical plants, and submarine oil-wells; from disposal of spent lubricants and other industrial and auto-motive oils; and by fall-out of airborne hydrocarbons emitted by vehicles and industry (see Table 6).

The actual amount that goes directly into the seas must be taken as proportionate to production. It is normally estimated at 0.1 per cent of production but if possible fall-out of airborne hydrocarbons on the sea surface is added it may be as much as 0.5 per cent.

This is because estimated emissions of hydrocarbons of petroleum origin to the air is 90 million tons, 40 times that emitted to the seas. Nobody knows how much may finally settle in the seas. SCEP points out that if "10 per cent does, then the total hydrocarbon contamination of the oceans could be almost five times the direct influx from ships and land sources."

The increase in the size of tankers must make things worse. The danger of large-scale accidents will increase with the scale of the tankers. 800,000 ton tankers are projected. "A single spill from one of these would add 20 per cent to the amount of oil entering oceans in a single year" (SCEP). Cleaning up oil spills does more harm than good "even with a non-toxic dispersant, the

Table 4

World Production[a] and US Consumption[b] of Toxic Heavy Metals
(Thousands of metric tons) (reproduced from SCEP)

	Hg		Cd		Pb		Cr_2O_3		Ni	
Year	World	US	World	US	World	US	World	US	World	US
1960	—	1.77	—	4.53	—	930	—	1,110	—	98.2
1961	—	1.92	—	4.65	—	932	—	1,090	—	108
1962	—	2.26	—	5.56	—	1,010	—	1,030	—	108
1963	8.28	2.70	11.8	5.19	2,520	1,060	3,920	1,080	340	114
1964	8.81	2.81	12.7	4.31	2,520	1,090	4,150	1,320	372	134
1965	9.24	2.54	11.9	4.75	2,700	1,130	4,810	1,440	425	156
1966	9.51	2.46	13.0	6.60	2,860	1,200	4,390	1,330	414	171
1967	8.36	2.40	12.9	5.28	2,880	1,150	4,300	1,230	441	158
1968	8.81	2.60	14.1	6.05	3,000	1,200	4,730	1,200	480	144[c]

[a] Sources: 1963 data are from the *Minerals Yearbook*, 1967; 1964-1968 data are from the *Minerals Yearbook*, 1968.
[b] Source: *Chemical Economics Handbook*, 1969.
[c] Source: *Minerals Yearbook*, 1968.

Table 5

Man-Induced Rates of Mobilisation of Materials Which Exceed Geological Rates As Estimated in Annual River Discharge to the Oceans
(Thousands of metric tons per year) (reproduced from SCEP)

Element	Geological Rates[a] (In Rivers)	Man-Induced Rates[b] (Mining)
Iron	25,000	319,000
Nitrogen	8,500	9,800 (consumption)
Manganese	440	1,600
Copper	375	4,460
Zinc	370	3,930
Nickel	300	358
Lead	180	2,330
Phosphorus	180	6,500 (consumption)
Molybdenum	13	57
Silver	5	7
Mercury	3	7
Tin	1.5	166
Antimony	1.3	40

Sources:
[a] Bowen, 1966.
[b] United Nations, *Statistical Yearbook*, 1967. Data for mining except where noted.

dispersed oil is mush more toxic to marine life than is an oil slick on the surface". (SCEP).

The effect of spills in shallow water is particularly damaging. Thus "an accidental release of 240 to 280 tons of No. 2 fuel oil from a wrecked barge off West Falmouth, Massachusetts in 1969 caused an immediate massive kill of organisms of all kinds—lobsters, fish, marine worms and molluscs".

The difficulty of estimating biological effects in coastal waters is that "many other pollutants are also present in this zone and it is hard to separate their different effects. Indeed, the effects may not be separable, but instead additive or mutually reinforcing".

One possible effect of oil dispersed over wide ocean areas could arise from the fact that "chlorinated hydrocarbons such as DDT and Dieldrin are highly soluble in oil film. Measurements . . . in Biscayne Bay, Florida showed that the concentration of a single chlorinated hydrocarbon (dieldrin) in the top 1 millimetre of water containing the slick was more than 10,000 times higher than in the underlying water . . . We know that the small larval stages of fishes and both the plant and animal plankton in the food chain tend to spend part of the night hours quite near the surface, and it is highly probable that they will extract, and concentrate still further, the chlorinated hydrocarbons present in the surface layer. This could have seriously detrimental effects on these organisms and their predators."

Implicit throughout this study is the knowledge that these ecologically disruptive trends cannot be allowed to persist indefinitely. SCEP concludes "In general, the expected losses from present impacts do not exceed our capacity to carry the burden; this leads us to the conclusion that an intractable crisis does not now seem to exist. Our growth rate, however, is frightening. The impact of two, four, or eight times the present ecological demand will certainly incur greater losses in the environment. If the process of change were gradual, the present ecological advantage that is reflected in our 5 to 6 per cent annual growth would taper off in the face of decreased environmental services, and growth would be correspondingly slowed. Instead, the risk is very great that we shall overshoot in our environmental demands (as some ecologists claim we have already done), leading to cumulative collapse of our civilisation. It seems obvious that before the end of the century we must accomplish basic changes in our relations with ourselves and with nature. If this is to be done, we must begin now. A change system with a time lag of ten years can be disastrously ineffectual in a growth system that doubles in less than fifteen years."

Table 6

Estimates of Direct Losses into the World's Waters, 1969
(Metric tons per year) (reproduced from SCEP)

	Loss	Percentage of Total Loss
Tankers (normal operations)		
Controlled	30,000	1.4
Uncontrolled	500,000	24.0
Other ships (bilges, etc.)	500,000	24.0
Offshore production (normal operations)	100,000	4.8
Accidental spills		
Ships	100,000	4.8
Nonships	100,000	4.8
Refineries	300,000	14.4
In rivers carrying industrial automobile wastes	450,000	21.6
Total	2,080,000	100.0

Table 7

Estimated Concentration Factors in Aquatic Organisms

Radionuclide	Site	Phyto-plankton	Filamentous Algae	Insect Larvae	Fish
Na^{24}	Columbia River	500	500	100	100
Cu^{64}	Columbia River	2,000	500	500	50
Rare earths	Columbia River	1,000	500	200	100
Fe^{59}	Columbia River	200,000	100,000	100,000	10,000
P^{32}	Columbia River	200,000	100,000	100,000	100,000
P^{32}	White Oak Lake	150,000	850,000	100,000	30–70,000
Sr^{90}-Y^{90}	White Oak Lake	75,000	500,000	100,000	20–30,000

Source: Eisenbud, 1963 (reproduced from SCEP).

APPENDIX B

Social Systems and their Disruption

The activities of industrial man are having a very serious effect on society. They can be shown to be leading to its disintegration, and it can also be shown that such pathological manifestations as crime, delinquency, drug addiction, alcoholism, mental diseases, suicide, all of which are increasing exponentially in our major cities, are the symptoms of this disintegration.

Unfortunately, before we can understand why and how this is happening, we must know a little more about human society. Sociology, which should provide us with this information, is failing to do so, mainly because it is studying human society "in vacuo", i.e. without reference to behaviour at other levels of organisation. This is the result of regarding man and the societies he develops as unique, and in some way exempt from the laws governing all the other parts of the ecosphere. If we establish this false dichotomy between man and other animals it is partly because we fail to understand the nature of the evolutionary process. Thus, owing to our tendency towards subjective classification, we recognise that certain events among which a connection can be made within our immediate experience can be regarded as constituting one process, while, on the other hand, we refuse to admit that this can be the case with events whose connecting bond lies outside our experience. Thus we are willing to admit that the development of a foetus into an adult is a single process, and that it is difficult to examine, separately and in isolation,

any of its particular stages apart from the process as a whole. On the other hand, we are less ready to regard evolution in this way.

We still imply that radical frontiers exist between life at different levels of complexity, in spite of the fact that they are part of the same evolutionary process. Yet, it can be demonstrated that no such frontiers obtain. When Kohler synthesised urea, the barrier between the "organic" and the "inorganic" was suddenly shattered, as was that between the "animate" and "inanimate" when the virus was found to manifest certain features associated with life on being confronted with a source of protein, and at other periods to display the normal behaviour pattern of a crystal. Again, it has been demonstrated repeatedly that no barrier exists separating man from other animals. He is more "intelligent" and that is about all that can be said.

If human societies are not unique, their functions cannot be understood apart from that of other natural systems, such as ecosystems and biological organisms, i.e. in the light of a general theory of behaviour.

To understand this, one must first realise that the vast and chaotic human societies in which we are living are by no means normal. If man has been on this planet for a million and a half years, which is possible, it is only in the last 150 years that he has become an industrialist, and that industry has permitted the development of such societies. This represents no more than two days in the life of a man of 50.

For more than one million four hundred and ninety thousand years he earned his living as a hunter-gatherer. During all this time, there is no reason to suppose that the societies he developed were in any way less adapted to their respective environments than are those of non-human animals.

From our knowledge of surviving hunter-gatherer societies, such as the Bushmen of the Kalahari, one can presume that they probably consumed less than a third of the available food resources. They did not clear forests for agricultural land, nor did they hack down trees for building houses, nor were they so short-sighted as to exterminate the wild animals on which they depended for their livelihood.

At the same time they avoided increasing their population over and above that which might lead them to have to alter their life-style in any way.

Even if one considers an area overpopulated, as does Professor Ehrlich[1], "when human numbers are pressing against human values", and not just when they actually starve, then such societies were never overpopulated.

What is more, the survival of such societies was compatible with that of climax ecosystems, to which they contributed by fulfilling within them their various ecological functions. Take the case of the Plains Indians of North America who lived off the vast herds of bison. They did not, on the whole, attack the main herd, which would have been a dangerous undertaking, but rather killed off the stragglers; the old and the weak, thereby exerting quantitative and qualitative controls on these animals.

It is significant that exactly the same is true of the lions living off the buffalo herds in East Africa.

If human societies for 99.75 per cent of their tenancy of this planet, behaved as an integral part of our ecosphere (before the invention of agriculture 10,000 years ago and industry 150 years ago) it is unreasonable to suppose that such behaviour is not subject to its laws.

Nor is there any reason why sociology should be anything but a branch of the natural sciences, that which deals with a particular type of natural system: the human society.

Let us briefly look at human society in this light.

First of all, like all other natural systems, a human society displays organisation. This is probably its most important feature. If one gathers on an island a random collection of people from different societies speaking different languages it would be naive to suggest that these constituted a society. Nevertheless there would be a tendency for organisation, or negative entropy, to build up (or entropy and randomness to be reduced). First of all men would pair off with women and have children. Families would be formed and groups of these families would tend to be associated and grow into small communities. As this occurred so their members would develop more and more things in common. They would learn to speak the same language and dress, eat and build their houses in a similar way. Slowly a common set of values and aspirations would emerge, and these would bind them together in a common purpose and transform them into a true society.

This organisational process is not a linear one. Thus, in its development from the simple to the complex, matter passes through certain critical stages, where the possibilities of a particular type or organisation are exhausted and further advance can only be achieved by the development of a new type.

Thus, an atom can be developed only up to a certain point. This point will vary with different types of atoms, some of which, such as the tungsten atom, are relatively large.

Beyond this critical point, however, development can occur only by the association of several atoms together to form a molecule. As soon as the latter stage is reached, the constituent atoms undergo a considerable change, in that a radical division of labour occurs, in accordance with the law of economy.

To explain their behaviour now requires the introduction of several new principles.

There is no reason to suppose that this notion of levels of organisation does not apply equally well to human social systems. Thus the family, which clearly represents the first level of human organisation, is a universal feature of all human societies, and there is no example of its suppression without the most serious social consequences. The family is held together by bonds which are extendable in the sense that the stimuli required for triggering off the corresponding behavioural responses are not specific as in the case of simpler forms of life.

For example, not only a mother, but a mother-like figure, can trigger off filial responses, or vice versa[2]. It is this feature of the family bonds which permits the development of larger social units. The latter can, of course, be of many kinds. They can be bilateral extended families, or unilateral, or the members of the different families constituting these units need not be related at all, as mere contiguity is sufficient to allow the development of such bonds[3]. Another essential characteristic of the family bonds is that they cannot be extended indefinitely. This is a feature of all bonds, whether they be holding together the nucleus of an atom or the solar system. A point must, therefore, be reached where the bonds cannot be extended any further, and development only becomes possible by the association of a number of such units. At this

point it can be said to have reached a new level of organisation.

Once we pass the level of the village, clan or lineage, we reach a level of social organisation that has not often been achieved by the human species. To harness the family bonds in such a way as to build up a larger unit requires the development of very elaborate forms of organisation. This involves "criss-cross" bonds that permit the establishment of a veritable cobweb of associations of one sort or another, all of which transcend each other in such a way that each individual is linked to each other member of the society in at least one, and preferably more ways.

Thus a tribesman is at once a member of a family, of a maternal and of a paternal kinship group. As neither of these may coincide with the social unit that is the village in which he lives, he is a member of yet another group: the village. He is also likely to be a member of an age grade, of a secret society of some sort, possibly also of a military club and of some other group with a common economic activity. Such a man has a very definite status which Linton[4] defines as "The sum total of all the statuses which he occupies and hence his position with relation to the total society".

The same principle is apparent in the more stable segment of our modern societies. As Linton writes: "... the status of Mr Jones as a member of his community derives from a combination of all the statuses which he holds as a citizen, as an attorney, as a Mason, as a Methodist, as Mrs Jones' husband, and so on." As a result of such criss-cross associations, a man is in contact with a very large number of cross-sections of the society. There is what Ortega y Gasset[5] calls "social elasticity".

All the parts of the society are in contact with each other. Any change in the society will, therefore, effect each individual and the actions of each individual must effect the society as a whole through the agency of all the associations of which he is a member.

Without social elasticity there would be no bonds, no organisation: in fact no real society. Yet social elasticity can only be maintained in special conditions. Thus it is likely that if the society grows too big, the bonds holding it together become of an ever more precarious nature and eventually incapable of holding it together.

The social system is, in fact, overloaded, with more people than it is capable of organising into a society. Its essential structure breaks down, and it ceases to be capable of self-regulation.

As already mentioned, it is a basic feature of all bonds that there is a limit to their extendability. Those holding together a community which are already extensions of the family ones, cannot be extended to hold together more than a certain number of people. Aristotle considered that a city could be made up of no more citizens than could not know each other by sight. The Greek city states which displayed some of the features of self-regulating units, were, in fact, very small. Only three had more than 20,000 citizens (Athens, Corinth and Syracuse). It is significant that a recent study in America has revealed that the crime rate appears to be proportionate to the size of the city. Violent crime appears to be about six times greater *per capita* in cities of 1 million people than in cities of 10,000.

Social elasticity is also seriously affected by mobility. It is impossible to create sound societies when people are being constantly moved from place to place. In such conditions, the towns are not made up of people who have grown up together and among whom bonds have had time to develop, but simply of people who have been thrown together for various random reasons. Bonds cannot be manufactured at will. Nor can that socialisation process that will enable people to fulfil their specific functions within their social system be compressed into a few years of adult life. It is a slow, educative process, the most important part of which must occur in the early years of life—when the generalities of a cultural pattern, i.e. its basic goals and values, are inculcated via the family and the small community.

To understand this principle, it is necessary to see how cultural information is used to determine the adaptive and self-regulatory behaviour of a social system, in fact, how the basic cybernetic model applies to a society.

If a society is capable of self-regulating behaviour, it is that its responses are based on a model of its relationship with its environment, in the light of which they are being continually monitored. Such a model is a society's world-view, or "Weltanschauung", which is compounded of its religion, mythology, traditional law, etc.

As soon as one understands a society's culture, one understands the reason for its behaviour and all its actions that previously appeared random or irrational, now appear quite logical. The following example illustrates this point.

It is well known that some Australian aborigines failed to establish a cause and effect relationship between copulation and conception. Instead, they generally believed that the spirits of children yet unborn, which were apparently referred to as "ngargugalla", inhabited some strange world from which they only emerged when dreamt of by their mothers. Daisy Bates[6] tells us that among the Koolarrabulloo it was the father who had to have such a dream:

> "They believed that below the surface of the ground and at the bottom of the sea, was a country called Jimbin, home of the spirit babies of the unborn, and the young of all the totems. In Jimbin there was never a shadow of trouble or strife or toil or death: only the happy laughter of the little people at play. Sometimes these spirit babies were to be seen by the jalngangooroo, the witch-doctors, in the dancing spray and sunlight of the beaches, under the guardianship of old Koolibal, the mother-turtle, or tumbling and somersaulting in the blue waters with Pajjalburra, the porpoise ...
>
> "... So firm was the belief in the 'ngargalulla' that no man who had not seen it in his sleeping hours would claim the paternity of a child born to him. In one case, that came under my observation, a man who had been absent for nearly five years in Perth proudly acknowledged a child born in his absence, because he had seen the 'ngargalulla', and, in another, though husband and wife had been separated not a day, the man refused absolutely to admit paternity. He had not dreamed the 'ngargalulla'. Should a boy arrive when a girl came in the dream, or should the ngargalulla not have appeared to its rightful father, the mother must find the man who has dreamed it correctly, and he is ever after deemed to be the father of that child."

It is evident that, if we were not aware of this aspect of the world-view or model of the Koolarrabulloo, we would find their attitude towards the acceptance of paternity totally illogical. However, once we were acquainted with

their model, their attitude would appear quite reasonable, and could even be predicted with a fair measure of probability. There is no reason why all seemingly irrational behaviour can be explained on the basis of a cultural model of this sort.

We regard as "rational", behaviour which is based on *our* cultural model of the world and which somewhat presumptuously we regard as the only valid one. However, if we realised that the object of cultural information is to mediate the behaviour that will lead a society to adapt to its particular environment, it then becomes apparent that whether or not this information constituted "scientific" knowledge is irrelevant, and hence our particular scientifically based culture is in no way superior to those developed by the most primitive societies.

Equally important is the fact that a culture also provides a society with a goal-structure and a means of achieving it. The goal of all self-regulating societies appears to be the acquisition of social prestige. It is important to realise that this goal is only possible in a closely knit society, in which there is fundamental agreement as to what are the determinants of prestige. These will vary in each society. In general one can say that these will coincide with the qualities that must be cultivated if the society is to survive. Thus in a society of hunter-gatherers, success in a hunt is likely to be a determinant of prestige; among societies involved in war-like pursuits courage is likely to be particularly prestigious. The prestige achieved will determine one's position in the social hierarchy. This hierarchy is of immense importance in avoiding strife and in ensuring a socially acceptable division of labour among the members of the society. If there is no hierarchy there will be constant bickering and fighting. There will also be no mechanism for ensuring the perpetuation of those qualities required if the society is to survive. Hierarchy is another word for organisation. There are only two ways of dispensing with it: one is to accept chaos and with it asystemic controls such as dictators, the other is to reduce the size of the society. In an extremely small social grouping such as the Kalahari Bushmen and the Pygmies of the Ituri Forest, the requirement for hierarchy is reduced to a minimum, and very stable egalitarian societies are possible. However, as the size of the groupings increases so must the requirement for hierarchy.

Each society has a whole set of beliefs regarding the supernatural forces that can be exploited to enable individuals, associations and society as a whole to achieve their ends.

Many ceremonies and rituals are performed to this end, all of which have the additional effect of tightening social bonds, and hence of further increasing social organisation. At the same time, every society has a set of taboos, basically to prevent supernatural forces from being mobilised to hinder the achievement of the society's goal-structure[7].

There is every reason that the goal that self-regulating societies set themselves is one whose achievement permits the satisfaction of the environment's many competing requirements and is not purely arbitrary as in the case of our society.

This may be illustrated by the way in which the size of the simple society is determined. Thus if the Eskimos live in small family units during the summer months, it is because there is no need for a larger unit, indeed the arctic areas they inhabit would not support one. If the Pygmies of the Congo live in small bands it is because this is the ideal number of people for survival in tropical rain forests, possibly providing the minimum number of hunters required to trap an elephant. If the society is truly self-regulating, however, it should be capable of reducing or increasing complexity to permit adaptation to changing environmental conditions—so long as these occur within certain limits. Thus when faced with the Macedonian menace, it would have been adaptive for the Greek city states to join together to form a league, i.e. to achieve a higher level of organisation. This they never really succeeded in doing, though there were many attempts.

On the other hand, in the absence of environmental challenges requiring action on the part of a larger, more complex social unit, it would be adaptive for complexity to be reduced, for the society to break up, temporarily at least, into its constituent parts. Usually, however, institutional barriers prevent this from occurring. Central governments are jealous of the territories that they control and usually refuse to face reality, once environmental conditions render superfluous and artificial the states that they control.

The important thing is that a self-regulating society must be goal-directed. It moves in a particular direction, and both the goal towards which it is moving, and that behaviour pattern that permits its achievement, are culturally determined.

For the society to keep moving in this direction, it means that all its members must be imbued with the cultural information that will enable them to fulfil their specific functions as specialised members of their social system. It also means that every cultural trait which we often tend to regard as being of little practical significance, and which our missionaries, educators, administrators, etc., are only too pleased to interfere with, has a specific function in the overall social behaviour pattern.

If one were acquainted with the culture of any stable society and were capable of working out the role played by each of the customs and institutions within this culture, i.e. by determining in what way they contributed towards the adaptive behaviour of the society to its particular environment, one could easily imagine what would be the consequences of their suppression by outside interference. Let us take the case of the marital customs of the Comorians, who inhabit a group of islands between Mozambique and Madagascar. The people of the Comores have a complex social organisation, probably based on indigenous customs upon which were superimposed those of their Islamic conquerors. From the former they inherited a matrilineal and matrolocal tradition; from the latter a patrilineal and patrilocal one. Islamic marital law has also been adopted. As a result, there is polygamy and a high frequency of divorce. Indeed, so high is the latter that it is perfectly normal for a woman to have been married five to ten times. From the experience gained in our society, we would tend to associate such a consequent number of "broken homes", with a very high rate of juvenile delinquency, schizophrenia and suicide, i.e. the symptoms of social disorder. However, things do not work out that way.

In Mayotte, one of the islands making up the Comores Archipelago, there have been only two deaths by violence in the last fifty years, and neither were premeditated murders. Crime in general is minimal, as are mental diseases, delinquency, suicide and the other symptoms of social disorder.

The society is thus culturally adapted to marital instability, which ours is not. The reasons are two-fold. First, by virtue of the institution of matrilinearity and matrilocality, a child is partly the responsibility of the mother's clan. Many of the functions of fatherhood are in fact fulfilled by the mother's elder brother, and inheritance, for instance, is primarily through him rather than through the father. Secondly, by custom, the step-father automatically assumes many of the responsibilities of fatherhood, *vis-à-vis* the children that his new wife has had with previous husbands. The step-father, or "baba combo", is, in particular, responsible for the payment of the very large expenses involved in the circumcision ceremony of his stepsons. Also, the father's role is reduced by the fact that the children are brought up in the mother's home. As the father probably has several other wives, he will in any case only be physically present in one particular house on one or two days a week. For all these reasons, divorce does not have the same unsettling effect in the Comores that it does in our society. Now, supposing a missionary or administrator suddenly decided that matrilinearity and matrilocality were vestiges of barbarity not to be found in modern civilised societies, and that they must, therefore, be abolished; unless he abolished at the same time many of the other customs making up this complex culture, the results would be disastrous. Schizophrenia, delinquency, and the other symptoms of social disorder would result, as they do in our society with the break-up of the nuclear family.

What is particularly striking about the self-regulating society is the absence of these forms of deviation. Crime is, in fact, an extremely rare occurrence in spite of the fact that there are no policemen, lawcourts, tribunals, etc. Indeed in such a society, there is no need for external controls of this sort. Systemic controls, i.e. those controls applied by the society as a whole through the medium of public opinion, are sufficient to prevent any deviation from the accepted norm[4].

As Linton writes: "The Eskimos say that if a man is a thief no one will do anything about it, but the people will laugh when his name is mentioned. This does not sound like a severe penalty but it suffices to make theft almost unknown. Ridicule will bring almost any individual to terms, while the most stubborn rebel will bow before ostracism or the threat of expulsion from his group."

Besides in a stable society, all the citizens will have the good of the society at heart. They will feel part of it and will all equally oppose the behaviour on the part of any of its members that is contrary to the established customs and that might compromise the interests of the society as a whole. Solon was once asked which was the best policed city[8]. "The city" he replied "where all the citizens, whether they have suffered injury or not, equally pursue and punish injustice." The same spirit that Solon expressed is apparent in Pericles' celebrated speech over the bodies of the first victims of the Peloponnesian war: "... We are prevented from doing wrong by respect for authority and for the laws, having an especial regard for those which are ordained for the protection of the injured, as well as for those unwritten laws which bring upon the transgressor of them the reprobation of the general sentiment."

We regard government, parliaments, and vast bureaucracies as essential to all societies. However, it is probable that most of the societies ever developed by man dispensed with such external controls. As Lowie writes[9]:

> "... it should be noted that the legislative function in most primitive communities seems strangely curtailed when compared with that exercised in the more complex civilisations. All the exigencies of normal social intercourse are covered by customary law, and the business of such governmental machinery as exists is rather to exact obedience to traditional usage than to create new precedents."

Indeed, in such societies, nothing can be found to correspond to our notion of government. There are no kings, presidents, or even chiefs, no courts of law, prisons or police force. The closest approximation to a political institution is the council of elders that occasionally gathers to discuss important issues. It is for this reason that the Australian aboriginal tribe has often been referred to as a "gerontocracy", or as a government by the old men—a title that can aptly be applied to most simple, ordered societies.

The absence of formal institutions, rather than give rise to the permissiveness that we would expect, is in fact associated with discipline and the strictest possible adherence to the tribal code of ethics. Behaviour which, in a disordered society, could only be exacted at the cost of brutal coercion, is with them ensured by the force of public opinion, the sanction of the elders, and the fear of the ancestral spirits.

In more advanced societies, we find the same principle obtaining in a less extreme form. Thus, in ordered societies where public opinion plays an important role, the need for strong government, and in particular, dictators, is correspondingly reduced.

Conversely, in these disordered societies where public opinion plays but a small part, we find that the absence of the most authoritarian government, linked to an all-pervasive and coercive bureaucracy inevitably leads to lawlessness and mob rule.

By causing the disintegration of a society, by overloading the social system with too many people, or by increasing mobility so as to prevent their proper socialisation, one is reducing the power of public opinion, and thereby the society's capacity for self-regulation. We are introducing asystemic controls in ever greater quantities: more politicians, more bureaucrats, more laws, more tribunals, so one is rendering the systemic controls ever more redundant, and further reducing a society's capacity for self-regulation.

A society used to being run in this manner ceases to be capable of running itself. In many South American republics, the deposition of one dictator will lead merely to the installation of another. Real democracy is not possible since the essential social structure for rendering it possible does not obtain. A mass democracy is, in fact, a contradiction in terms, and as our society becomes ever more massive and ever less organised, i.e. as entropy and randomness increase, so must there be a proportionate increase in the precarious asystemic controls required to maintain a semblance of social order, and a similar reduction in its stability and hence in its capacity to survive.

We can thereby formulate the essential principle that the higher the entropy or randomness of a social system, the greater must be the need for asystemic controls of which the most extreme kind is a dictator.

Such controls are as unsatisfactory in social systems as they are in ecosystems, and for the same reasons. A dictator gears his society to the achievement of what is usually an arbitrary goal regardless of environmental requirements. This can therefore only increase the society's instability.

As we have seen, it creates a need for further dictatorship by destroying natural systemic controls which it renders redundant.

It is also highly vulnerable. One can exterminate a large proportion of the population of a self-regulating society without affecting its organisation or its capacity to govern itself, whereas in a dictatorship, it suffices to kill the dictator for the society to be plunged into chaos and civil war, a point that is particularly well illustrated by the experience of the later Roman Empire.

Dictatorship, in other words, involves a drastic simplification of a society's control mechanisms, and must determine a corresponding reduction in its stability.

Our industrial society is further affecting human society by absorbing non-industrial cultures. Whereas there were previously innumerable cultures geared to totally different ends, so, as they fall within the orbit of industrial "civilisation", they come more and more to resemble each other.

It is significant that in New Guinea, that last great reservoir of primitive cultural wisdom, there are still 700 different cultural patterns, each with its own distinct language. In such circumstances mistakes committed by one such social group are likely to have the minimal effect on the others and the probability that at least one cultural pattern provides the solution to a new environmental problem is maximised.

The absorption of these diverse highly differentiated societies into a common mass-society geared to the achievement of short-term material ends is a loss to humanity that cannot be over-emphasised.

It must seriously reduce the complexity and hence the stability of human social organisations on this planet. It must also lead to the irreparable loss of a vast store of cultural information which is as important to man's survival as is the store of genetic plant variety so seriously compromised by modern agricultural techniques.

Social disruption and its effects

There is increasing evidence that deprivation of a satisfactory family environment will affect children profoundly and colour every aspect of their later life.[10] Such children are often referred to as emotionally disturbed. However bright they may be, they will tend to find it very difficult to fit into their social environment, the reason being that the early and most important stages of socialisation were badly impaired. The earlier family deprivation occurred, the more will this be the case, for as D. O. Hebb[11] shows, the effect of early experience on adult behaviour is universally correlated with age.

Sadly, it is rarely possible for socially deprived and emotionally disturbed children to be satisfactorily socialized. No amount of school education can do much for them.

They are characterised by their inability to accept any social constraints. They are unable to concentrate on their work and are only interested in things which are of apparent immediate advantage to them. Regardless of their intelligence level, they are thus extremely difficult to educate. They are particularly concerned with the present, and the short-term, and are predisposed to all pathological forms of behaviour such as delinquency, drug addiction, alcoholism and schizophrenia.

What is worse, when they grow up, they are unlikely to be capable of fulfilling their normal family functions; their children, consequently also deprived of a normal family environment, will in turn tend to be emotionally unstable.

John Bowlby went so far as to compare a delinquent with a typhoid carrier[12]. He is as much a carrier of disease as the latter—of a disease of the personality which will affect his family and his community for generations, until his descendants are eliminated by natural selection.

Socially deprived, emotionally disturbed youths are a feature of disintegrating societies. In the black ghettoes of New York and other large American cities, they are the rule rather than the exception. There is increasing reason to suppose that the low standard of achievement and the high rate of crime, and various forms of retreatism that characterise such societies are mainly attributable to family deprivation.

If a child is seriously affected by being deprived of a satisfactory family environment, an adult is also adversely affected by being deprived of a satisfactory communal environment.

As we have seen, in a stable society, a cultural pattern provides an individual with a complete goal structure and an environment within which these goals can be satisfied.

In a stable society the principle goal appears to be the acquisition of prestige, to be looked up to by one's family and community.

In our industrial society, prestige is achieved in a variety of ways, including the right education, entering a socially acceptable profession and perhaps most important of all, making money.

Those who have not been subjected to the normal socialisation process and in particular members of different minority ethnic groups, may for various reasons, find these avenues of success barred to them. In such conditions they have no alternative but to develop a substitute set of goals. Cloward and Ohlin[13] interpret the development of a criminal sub-culture in the slums of a big city in these terms. It provides people with a new set of goals which they can achieve. Once crime becomes big business, and requires the same sort of qualities that permit success in the mainstream culture, then a further substitute outlet is required.

It is in these terms that Cloward and Ohlin interpret the "violent gang" sub-culture which also has its own ethic and goal structure, so different from the mainstream culture. However, those who have not succeeded in shedding the latter's values find themselves incapable of participating in it. They are forced to indulge in one or other form of retreatism—to isolate themselves psychologically from an environment which not only fails to provide them with an essential set of goals but also denies them.

Merton[14] describes a retreatist in the following way: "... Defeatism, quietism and resignation are manifested in escape mechanisms which ultimately lead him to 'escape' from the requirements of the society. It is thus an expedient which arises from the continued failure to near the goal by legitimate measures and from an inability to use the illegitimate route because of internalised prohibitions, this process occurring while the supreme value of the success-goal has not yet been renounced. The conflict is resolved by abandoning both precipitating elements, the goals and the means. The

escape is complete, the conflict is eliminated and the individual is associalised."

In a disintegrating society one would tend to find sub-cultures developing along all these different lines in varying degrees, i.e. there will be an increase in delinquency, violence and all the various forms of retreatism, such as drugs, drink, strange religious cults, etc, and mental disease. Such a society will be characterised by a general feeling of aimlessness, a frantic, almost pathetic search for originality, over-preoccupation with anything capable of providing short-term entertainment, and beneath it all a feeling of hopelessness of the futility of all effort.

Crime

In the United States, according to Mr John Mitchell, Attorney-General, crime in cities of more than 250,000 inhabitants is two and a half times that of the suburbs, which in turn is twice that of rural areas, Crime, needless to say, is on the increase. In the United States it has doubled in the last 10 years. In 1969 there were 2,471 crimes per 100,000 inhabitants. There were 655,000 violent crimes and 4,334,000 crimes against property, 14,590 murders, 36,470 rapes and 306,420 aggravated assaults. This is an increase of 12 per cent over the previous year. In the United Kingdom, crime is increasing at a similar rate. In 1970, according to a *Newsight* investigation, there were 1½ million indictable crimes, 300,000 in London alone, an increase of about 10 per cent over 1969.

Crimes of violence and burglary and battery in particular are increasing at the fastest rate, at more than 15 per cent per annum. There are at present 66 crimes of violence per 100,000 people in the United Kingdom as opposed to 324 per 100,000 in the United States. At the present doubling rate of five years it will take approximately 12 years to achieve the US rate of 324 per 100,000 which is so bad that life in cities has become intolerable and economic activity seriously menaced.

Professor Michael Banton of the Department of Sociology, Bristol University, told the British Association for the Advancement of Science that "increased disorder is part of the price we pay for the adaptation of our social arrangements to an economic system which brings us such great material benefits".

The relationships between crime rate and urbanisation has been established in a recent study in the US (see Table 8) which shows that it is considerably higher *per capita* in cities of more than 250,000 than in small towns with a population of less than 10,000.

Crime is part of the price of affluence, or more precisely, of the social disintegration that affluence gives rise to.

Perhaps the most damning indictment of our industrial society is the behaviour of people when the elaborate mechanisms of the law are for some technical reason put temporarily out of action.

In Montreal, during a 24-hour police strike, shops were pillaged, women raped and houses burgled.

In London, during a power strike, theft increased to such as extent in shops and department stores that many had to close until the light came on again.

Nothing better illustrates what can happen when the self-regulating mechanisms which normally ensure the orderly behaviour of the members of a stable society break down and are replaced by a precarious set of external controls.

Illegitimacy

As the family unit breaks down, it is not surprising to find that illegitimacy, another symptom of social disintegration, increases. Nor is it surprising to find that it is closely linked with other symptoms of social disintegration. According to W. R. Lyster, an Australian statistician, "Crime and illegitimacy rates are simultaneous in their incidence. The illegitimacy rate in England and Wales per 100 of all births has increased since 1955 from 4.7 to 7.8; crime has increased from about 45 per 10,000 to 120 per 10,000; thus, both have more than doubled."

Illegitimacy is costing our government £52 million per year. In industrial slums and other societies that have reached the more advanced stages of disintegration it is not unusual to find that up to 70 per cent of children are illegitimate.

W. A. W. Freeman, President of the Children's Officers Association, has recently reported a startling increase in the number of women who are simply abandoning their children, something which would not occur in a stable society.

Alcoholism

For each specific cultural pattern there must exist an optimum degree of alcohol consumption. It is likely that increases over and above this level will be in direct proportion to the development of disorder within the society itself. The number of offences of drunkenness proved in England and Wales for the year 1967 is greater than the number of offences proved in previous years. The increase as expected occurred in the large cities, the City of London having 476.43 offences for each 10,000 of its population. The Home Office with characteristic ignorance of basic sociological matters writes, "No reason for the increase can be adduced. There was no significant change in the liquor licensing laws."

According to the National Council on Alcoholism, alcoholism is costing the country about £250 million a year, mainly by absenteeism from work.

Table 8

Increase in Crime Rates With Increase in Size: Urban Crime Rates per 100,000 Population 1957

	Size of cities		
	over 250,000	50,000 to 100,000	under 10,000
Criminal homicide			
Murder, non-negligent manslaughter	5.5	4.2	2.7
Manslaughter by negligence	4.4	3.7	1.3
Rape	23.7	9.3	7.0
Robbery	108.0	36.9	16.4
Aggravated assault	130.8	78.5	34.0
At this point the scale changes			
Burglary, breaking or entering	574.9	474.6	313.3
Larceny-theft	1,256.0	1,442.4	992.1
Auto theft	337.0	226.9	112.9

Reproduced by courtesy of the Pemberton Publishing Co. from *Population Versus Liberty* by Jack Parsons.

About seven workers out of every thousand have drinking problems, and there are about 400,000 alcoholics in the country, a figure which is increasing annually.

Mental Health

Social disintegration is a major cause of mental disease. When an individual deprived of his essential social and physical environment is incapable of building a substitute one, or fails to isolate himself from the one he can no longer tolerate, by means of drugs or alcohol, his behaviour pattern, no longer adaptive to an environment for which it was not designed, tends to break down. One remaining position of defence is to build up his own personal world of fantasy which contains just those environmental constituents of which he has been deprived, and which he most requires.

There is considerable evidence to show that members of a society undergoing acculturation, whose culture is breaking down under the influence of an alien one are particularly prone to mental disease.

As national boundaries break down, small communities are swallowed up by vast urban conglomerations, mobility is increased and people move about the place in search of better pay, so cultural patterns break down.

In the United Kingdom, mental disease is increasing at a phenomenal rate. According to Ministry of Health statistics 169,160 people were admitted to hospitals in England and Wales in 1967 suffering from mental illness, two and a half times as many as in 1951.

There were 600,000 mentally disordered people in England and Wales in 1967, 186,901 of them occupying hospital beds or 46.6 per cent of all hospital beds. Thirty-two million working days every year are lost because of mental illness, representing a cost to the nation of £100 million, and local authorities spent £20,250,000 in mental health, more than six times what was spent in 1957.

Suicide

Durkheim regarded suicide as the ultimate manifestation of anomie. He found that the suicide rate was particularly low in poor rural communities where social structures were intact, and high in disintegrating affluent societies, especially among the working classes and even more so among immigrants, in this case Italians to the cities of Lorraine.

He goes so far as to say that "suicide varies in inverse proportion to the degree of integration of the social groups to which the individual belongs".

In Britain the suicide rate has fallen over the last six years by about 200 a year. Nevertheless, according to the Samaritans, a lay organisation that helps depressed and potentially suicidal people, the number of potential suicides has more than doubled in the last two years.

In 1967 their seven London area branches dealt with 5,999 new cases. In 1969 the same branches dealt with a further 11,641 cases. The Reverend Basil Higginson, an official of this organisation, estimates that cases would go on rising at this rate.

Conclusion

There is every reason to believe that the social ills at present afflicting our society—increasing crime, delinquency, vandalism, alcoholism as well as drug addiction—are closely related and are the symptoms of the breakdown of our cultural pattern which in turn is an aspect of the disintegration of our society. These tendencies can only be accentuated by further demographic and economic growth. It is chimeric to suppose that any of these tendencies can be checked by the application of external controls or by treating them in isolation, i.e. apart from the social disease of which they are but the symptoms.

It is the cause itself, unchecked economic and demographic growth, that must be treated. Until such time as the most radical measures are undertaken for this purpose, these tendencies will be further accentuated—until their cost becomes so high that further growth ceases to be viable.

APPENDIX C

Population and food supply

It is a common assumption that throughout the entire history of mankind, human populations have expanded whenever conditions permitted. Thus it is argued that during the 100,000 generations in which our forebears lived by food-collecting, the difficulties of keeping body and soul together were so great that populations were limited largely by crude food availability. Then with the adoption of agriculture, some 200 to 300 generations ago, the new-found sources of food permitted populations to expand until generally-speaking they were held down only by disease. Finally, modern public health methods, principally greatly improved sanitation and vector control procedures, permitted the phenomenal increases which collectively are known today as the population explosion.

Yet there is now good evidence that many of the human societies living before the agricultural revolution (and a few after) were stable societies in the strict sense of the phrase: i.e. they were regulated not by starvation, disease or war, but by cultural controls which only now we are beginning to understand. Why these controls disappeared we do not know. For the time being, however, we may speculate that they were lost in the cultural changes such societies must have undergone in response to the immense ecological changes brought about by each advance and retreat of glaciation during the Pleistocene Ice Age.

Since in a nutshell the problem of populations and food supply is how to live within one's ecological means without being forced to do so by naked hunger, it is worth bearing in mind that man (like many other animals) is potentially capable of so doing. In the meantime, we are faced with the task of reducing birth rate to compensate for the fall in death rate, because daunting though it undoubtedly is, the alternative of satisfactorily feeding an expanding population is still more so. Nonetheless, so far attempts to reduce birth rates have been largely ineffective on a global scale and even if they were to be successful it is unlikely that they could produce significant reductions in population growth rates within the time scale required to avoid major food shortages.

It is argued that the raising of living standards will, of itself, limit population growth by offering economic incentives that are reduced if the ratio of wage-earners to dependants within the family group is weighted too heavily in favour of dependants. Evidence of this is contradictory, although it is true that families have become smaller in Europe as levels of material prosperity have risen. However, it is not possible that this situation can be repeated throughout the world as a whole. The planet lacks the resources to permit the

industrialisation that would be required and even if these were to be found the levels of pollution generated by such a level of industrial activity would be greater than could be absorbed by the ecosphere. Even then, although the rate of increase would be reduced, populations would continue to grow.

The population of Britain is growing at 0.5 per cent per year, which gives it a doubling time of 138 years. While this is much lower than the world average (1.9 per cent each year) each individual within an industrial society consumes far more resources and contributes far more to environmental pollution than an individual in an agrarian society. Prof Wayne Davis[1] considers that an American has 25 times the impact on the environment as an Indian so that, worked out in terms of "Indian equivalents", the population of the United States is equivalent to that of 5,000 million Indians. Thus the problem of population is more acute in developed than in developing countries.

We must consider whether it is possible for the planet to provide food in sufficient quantities to sustain the populations that are forecast.

Food production may be increased either by extending the area under cultivation or by intensifying production on existing farmlands, or by both. Current FAO programmes concentrate on intensifying production on existing farms.

The extension of agriculture into marginal lands is expensive in terms of investment and produces only limited returns. It is more rational to direct such capital as is available into the improvement of existing farming.

Indeed, the amount of marginal land available for agriculture is severely limited and it has been estimated that if the required increases in food production were to be met from this source alone, the reserves of land would be exhausted within a decade or less[2]. Of a total land area of 32.5 billion acres estimates indicate that only 3 billion are cultivated at the present time[3]. Most of the world's land surface is occupied by the icecaps and permafrost, deserts, forests and urban and industrial areas. Sometimes it is suggested that the remaining tropical forests, in Amazonia in particular, might be cleared to provide agricultural land. It is unlikely that such schemes could be successful, even if the resources were available to carry them out. Experience with clearing primeval forest in Central America has shown that the removal of the climax vegetation triggers an erosion process leading to desert. The process is all but irreversible for organic matter once exposed is quickly mineralised. The unstable lateritic soils of Amazonia are 70 feet thick but they would be likely to erode very quickly if they were unprotected against the equatorial climate, while this itself would certainly be affected by the removal of such a large area of forest. When Kruschev cleared the forests in Kazakhstan for agriculture he left a dust bowl of some 30 million acres, an area equivalent to the entire agricultural land area of the British Isles.

The US President's Science Advisory Committee estimated in 1967 that the total arable and potential arable land in the world amounted to 8 billion acres. While some expansion is possible it is unlikely that the resources of capital and materials can be made available to produce more than minor increases in food production from these sources. There is little marginal land remaining for development in the Soviet Union, China, Asia or Europe and extension of farmlands in the more arid regions of the Middle East and North Africa would require new sources of fresh water for irrigation that are not available at present and will not be within the immediate future. It is possible that the United States might increase its area under cultivation from 300 to 350 million acres[3].

In fact, it is likely that existing agricultural land will be reduced as demands for urban and industrial development with all that that implies in terms of roads, airports, railways, etc., are met. Between 1882 and 1952 the total land area of the world occupied by permanent buildings has increased from 0.87 billion to 1.6 billion hectares[2]. This will be much higher if, by the year 2000, 81 per cent of the population of the developed countries and 43 per cent of the population of developing countries will be living in urban areas (Table 9).

Beyond a certain point, which varies with climate and soil type, the intensification of farming causes soil deterioration and eventually erosion. This is already a problem in many of the developed countries, where very intensive farming systems have been imposed. The extension of monocultural arable farming, the heavy use of artificial

Table 9

Changes in Land Utilisation 1882-1952

(In billion hectares) (reproduced from G. Borgstrom, *Too Many*)

	1882	Percentage	1952	Percentage	Change 1888-1952	Change Percentage
Forest	5.2	45.4	3.3	29.6	−1.9	− 36.8
Desert and wasteland	1.1	9.4	2.6	23.3	+1.5	+140.6
Built-on land	0.87	7.7	1.6	14.6	+0.73	+ 85.8
Pastures	1.5	13.4	2.2	19.5	+0.7	+ 41.9
Tilled land	0.86	7.6	1.1	9.2	+0.24	+ 24.5
	9.53	83.5	10.8	96.2	+1.27	+ 12.9
Area not especially utilised	1.81	16.5	0.27	3.8	−1.54	− 79.9
Total	11.34	100	11.07	100	−0.27	— 2.4

Source: R. R. Doane, 1957. *World Balance Sheet* (Harper, New York).

Table 10

Quality Classification of Tilled Land

	1882 Percentage	1952 Percentage
Good	85.0	41.2
Half of original humus lost	9.9	38.5
Marginal soils	5.1	20.3

Source: R. R. Doane, *loc. cit.* (reproduced from G. Borgstrom, *Too Many*).

fertilisers, the use of heavy machinery and, in other areas, overstocking with farm animals, all contribute to deterioration in soil structures, leading to a loss in the efficiency of drainage systems and in the effectiveness with which soluble fertilisers can be used. In this situation irrigation can lead to problems of waterlogging and/or salinity, while the overconsumption of groundwater for irrigation purposes can lead to a lowering of water tables that may compromise the future of farming. In large parts of Texas, for example, the present long drought is exacerbated by low water tables and it is possible that farming in Texas may have to be abandoned altogether.

The deterioration of soil structure has been observed in Britain, where stable soils and a temperate climate provide near-ideal farming conditions. In more severe climates and on poorer soils erosion is likely to appear more quickly and once it begins it could become an accelerating process. As the poorer lands fail the pressure on the better lands will increase, so tending to encourage still further intensification which will damage soils more rapidly than might be anticipated (see Table 10).

Erosion of farmlands in some areas is associated with the spread of deserts. In 1882 the world had a total 1.1 billion hectares of desert and wasteland. In 1952 the area had increased to 2.6 billion hectares[3] (see Table 9).

Given that demand for land must increase with population growth, and that populations are increasing exponentially, and assuming that the *per capita* requirement of land is 0.4 hectares for agricultural purposes and 0.08 hectares for non-agricultural purposes (a low estimate), Meadows[4] has shown that by the year 2000 the land available is likely to have decreased by 250 million hectares, while the demand will have increased by about 2.4 billion hectares, and that somewhere between 1980 and 1990 the demand for land will exceed the supply. Furthermore, if yields per acre were to double, the effect would be to add no more than 30 years to the world's food supply. Similarly a quadrupling of yield, which no serious person would consider possible, would add only 60 years. The net demand for food, then, will double every 30 years and it can be satisfied only by doubling yield every 30 years.

Britain has one of the most intensive farming systems in the world. In the 25 years since the end of World War II very large sums of money have been invested in technological developments aimed at increasing output and reducing the requirement for labour. Nevertheless, when the effect of inflation on farm prices is taken into account, the productivity of British agriculture has increased by only 35 per cent and there is good reason to suppose that in most major products yields have now levelled off and in some they are declining. Short of major technological breakthroughs in plant genetics and, possibly, the introduction of entirely new concepts in farming, none of which is in sight at present, it is extremely unlikely that agricultural production in Britain can achieve further significant increases. It is not possible for agriculture in developing countries to receive the heavy investments that British agriculture has received and so it is unlikely that increases in production can be achieved to match those in Britain. Even if they were, they would be insufficient, even to sustain the present inadequate dietary levels. Although the so-called "Green Revolution" has produced important improvements locally, overall the world food situation shows no sign of improving, and there seems little chance of the FAO's targets for 1985 being met.

In past years local emergencies have been alleviated by the provision of food, principally grains, from world stocks, which have been held mainly in North America. These stocks have been allowed to run down and so even this "cushion" is lost.

There are definite biological reasons for the limits on food production. Plants depend on a complex mixture of inputs, many of which are beyond man's control. Even of the principle requirements—sunlight, water and nutrients—it is only nutrient that man has succeeded in manufacturing and supplying to his crops. Fertiliser use is subject to diminishing returns beyond certain levels of application and these may be much lower in the field than controlled experiment under near-laboratory conditions would suggest. Thus an 11 per cent increase in the agricultural pro-

Table 11

World Average Rates of Increase for the Period 1951-1966 for Selected Aspects of Human Activity Related to Food Production

	Percentage[a]
Food	34
Tractors	63
Phosphates	75
Nitrates	146
Pesticides	300

Source: Digested from United Nations, *Statistical Yearbook*, 1967 (reproduced from SCEP).
[a] Rates in constant dollars.

Table 12

Pesticides Needed to Increase Food Production on Acreage now under Cultivation in Asia (except Mainland China and Japan), Africa, and Latin America by the Percentages Indicated

Percentage of Increase in Agricultural Production	Tonnage Needed (metric tons)
—	120,000
10	150,000
20	195,000
30	240,000
40	285,000
50	342,000
60	402,000
70	475,000
80	558,000
90	640,000
100	720,000

Source: President's Science Advisory Committee (PSAC), 1967 (reproduced from SCEP).

duction in the United States between 1949 and 1968 was achieved with a 648 per cent increase in the use of nitrogen fertiliser while Britain's 35 per cent increase required an 800 per cent increase in nitrogen fertiliser consumption. The consumption of pesticides to control the effects of the ecological imbalances created by the farming system has increased also. Between 1950 and 1967 US pesticide consumption increased by 267 per cent and achieved a 5 per cent increase in total crop yields[6].

The use of agrochemicals on a large scale makes a serious contribution to the pollution of the global environment. They are biologically potent, which is why they are used, and when introduced at random into the environment they interfere with living processes. Many pesticides affect the central nervous system of man, they may interfere with hormone secretions and some are known to be carcinogenic or teratogenic. Under certain circumstances some fertilisers can be harmful to health and by forming random associations with amines present in the environment, nitrites can become nitrosamines, which are carcinogenic. There is no way of knowing the extent to which the environmental carcinogen and mutagen loads have been increased because it is impossible to monitor all the possible interactions between pollutant and pollutant and between pollutants and substances present naturally. Pesticides that are persistent accumulate along food chains, so depressing predator populations and, in the long run, tending to encourage increases, rather than decreases, in pest populations. Organochlorine insecticides are particularly harmful to fish. Excess fertilisers enter water systems where they contribute to eutrophication problems. There must be an upper limit to the tolerance of the ecosphere to pollution from agriculture.

The effectiveness of pesticides is further reduced because insects, weeds and micro-organisms acquire resistance to them. Such resistance is based on hereditary characteristics in certain individuals within populations. It is transmitted genetically and so repeated application leads to the build-up of a resistant pest population by a process similar in all ways to natural selection. Throughout the world there are now some 250 species of insect pest that are immune to most insecticides[7].

In common with most organic chemicals, pesticides are derived from petroleum and their continued production is related to the availability of petroleum or of an alternative source of raw materials, although any alternative is likely to be more expensive. All agrochemicals consume power and water in their production and the availability of cheap sources of power and plentiful supplies of water is liking to limit any increase in production.

The intensification of agriculture in many areas of the third world would require much improved systems of transport to convey fertiliser, pesticides, machinery and seeds in and food out. It is doubtful whether the capital is available to develop such transport systems or the fuel to power them.

It is unrealistic to suppose that there will be increases in agricultural production adequate to meet forecast demands for food, and the notion that technological inputs can be made available that would guarantee a doubling of production by 1980 and a further doubling by 2100 is no more than fantasy. Such a thesis can be advanced only by "experts" who fail to take into account basic ecological, physical and biological principles, or who are not in possession of all the relevant information.

The intensification of agriculture cannot prevent famines within the next 15 to 20 years, probably affecting parts of Asia, Africa, the Near East and Latin America. Indeed, by causing further disruption to terrestrial and marine ecosystems it must reduce the capacity of the planet to support life.

Attempts to increase the world's protein availability from fisheries show no sign of solving the problem. The seas are experiencing serious pollution which may be undermining the phytoplankton that form the base of the marine biotic pyramid, and they may be overfished. In 1969, for the first time in a quarter of a century, total fisheries production did not increase, owing to poor catches, and this in spite of heavy capital investment by the developed countries. Fishery vessels are operating in deeper and more remote waters and owing to the high levels of investment in ships and processing plant the developed countries, which are also the major fishing nations, are irrevocably committed to increasing yields by a large factor within a very short space of time. In their efforts to do so there is little reason to suppose that they will not so deplete fish stocks that within a decade or so the contribution of fisheries to world food supplies will reduce rather than increase. If there is a temporary increase, little of this will benefit the developing countries which by and large cannot afford to participate in such a heavily capitalised operation. At present less than 20 per cent of the world's total catch of sea and fresh water fish is consumed within the third world.

APPENDIX D

Non-renewable resources

Introduction

For the purposes of this discussion, non-renewable resources are divided into two types: metals and fuels.

Metals

The 16 major metals we are concerned with are:

Silver (Ag)
Aluminium (bauxite) (Al)
Gold (Au)
Cobalt (Co)
Chromium (Cr)
Copper (Cu)
Iron (Fe)
Mercury (Hg)
Manganese (Mn)
Molybdenum (Mo)
Nickel (Ni)
Lead (Pb)
Platinum (Pt)
Tin (Sn)
Tungsten (W)
Zinc (Zn)

As can be seen from the chart on p.7, at present rates of consumption all known reserves of these metals will be exhausted within 100 years, with the exception of six (aluminium, cobalt, chromium, iron, magnesium and nickel). However, if these rates of consumption continue to increase exponentially at the rate they have done since 1960, then all known reserves will be exhausted within 50 years with the exception of only two (chromium and iron)—and they will last for only another 40 years!

Of course this is by no means the whole picture: there will be new discoveries and improvements in mining technology, and we can turn to recycling, synthetics, and substitutes. It should be obvious, however, that recycling, although a necessary and valuable

expedient in a stable economy, cannot supply a rising demand (it is not a source of metals, merely a means of conserving them); while synthetics and substitutes cannot be imagined into production, but must be made from the raw materials available to us, those most suitable being themselves in short supply. Petroleum, for example, from which many valuable synthetic polymers are derived, will run out within the lifetime of those born today and will probably be increasingly scarce—and correspondingly expensive—from about the year 2000. Improvements in mining technology will be necessary in any case if we are to make use of the lower grades of ore that will be the only ones available to us as reserves are depleted. However, exponential increases in consumption will inevitably lead to a situation in which grades decline much faster than technology is improved and costs will therefore soar. Similarly, as William W. Behrens[1] has shown, the dynamic of exponential growth will considerably reduce the lifetime of new discoveries. For example, even if reserves of iron (which has a relatively long lifetime) are doubled, they will stave off exhaustion for only another 20 years. Thus, given present rates of usuage and the projected growth of those rates, most raw materials will be prohibitively expensive within about 100 years. Political difficulties will arise well before then—as indeed they are beginning to do in the case of oil.

As Preston Cloud[2] has pointed out, the extra iron, lead, zinc and so on, necessary to raise the level of consumption of the 3,400 million non-Americans to that of their fellows in the United States is from 100 to 200 times present annual production—and although this would be exceptionally difficult to achieve, it is paltry compared with the problem of providing an equivalent standard of consumption for the doubling of world population projected for 40 years' time. And yet we in the industrial countries expect our consumption of metals to go on rising and at the same time lure the non-industrial countries with promises that they too can have "wealth" like ours!

Only those acrobats of the imagination who argue that, come what may, technology will find a way, believe that problems such as these can be solved in any way save a diminution of consumption. In particular, they are confident that the abundance of cheap energy they assure themselves will be available in the near future will enable us to extract the metals present in ordinary rock and in seawater. Yet energy is already very cheap (comprising only 4.6 per cent of the world's total industrial production by value)[3], while the real limit on such enterprises is likely to be not energy but the fragility of ecosystems. For example, the ratio of unusable waste to useful metal in granite is at least 2,000 : 1, so that the mining of economic quantities of metals from rock or seawater will very quickly burden us with impossible quantities of waste.

Energy

The bulk of our energy requirements today is met by fossil fuels, which like metals are in short supply. At present rates of consumption, known reserves of natural gas will be exhausted within 35 years, and of petroleum within 70 years. If these rates continue to grow exponentially, as they have done since 1960, then natural gas will be exhausted within 14 years, and petroleum within 20. Coal is likely to last much longer (about 300 years), but the fossil fuels in general are required for so many purposes other than fuel—pesticides, fertilisers, plastics, and so on—that it would be foolish to come to depend on it for energy[4].

Recognition of this has led to the present emphasis on nuclear fission as a source of energy. However, the only naturally occurring, spontaneously fissionable source of energy is uranium 235, and this is likely to be in extremely short supply by the end of the century[5]. Accordingly, the future of nuclear power rests with the development of complete breeding systems. Breeder reactors use excess neutrons from the fission of uranium 235 to convert non-fissionable uranium 238 and thorium 232 into fissionable plutonium 239 and uranium 233 respectively. Their successful development will mean that man's energy needs will probably be met for the next 1.000 years or so, during which time it is hoped that deuterium-deuterium fusion can be developed—which will provide us with virtually unlimited energy.

Because the successful development of breeder reactors in time to take over from fossil fuels is possible, it may be that fuel availability will not be a limiting factor on growth. This means nothing, however, since shortages of other resources and pollution by radioactive by-products and waste heat will quickly prevent the continued expansion of energy consumption. Since radioactive pollutants have been dealt with in the appendix on ecosystems, we will here consider only waste heat.

Every use of energy always produces waste heat. Power stations "solve" the problem of heat production either by using large amounts of cooling water, or to a lesser extent, air. The disadvantage of the former method is that if the heated water is returned to source it damages the aquatic ecosystem, and if it is evaporated into the atmosphere the source is considerably depleted. The disadvantage of the latter method is that because air temperatures are higher than those of water, the thermodynamic efficiency of the power station is much reduced.

Efficiency is a great problem. In the US, electricity provides 10 per cent of the power actually used by the consumer, but accounts for 26 per cent of gross energy consumption. Earl Cook[6] has calculated that at present rates, by the year 2000 electricity will provide 25 per cent of "consumer-power" and account for between 43 and 53 per cent of gross energy consumption. At that point, half the energy produced will be in the form of useful work and half in the form of waste heat from power stations.

Even if we ignored the waste heat from power stations, that produced by the actual consumption of electricity will quickly call a halt to growth. For example, in the US in 1970, heat from that source amounted to an average of 0.017 watts per square foot, and Claude Summers[7] has calculated that if consumption continues to double at the present rate, within only 99 years, after 10 more doublings, the average will be 17 watts per square foot—compared with the average of 18 or 19 watts the US receives from the sun! Clearly, well before this point energy consumption will be limited by the heat-tolerance of the ecosphere.

A BLUEPRINT FOR SURVIVAL

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[From the Ecologist, March 1972]

A Blueprint for Survival

COMMENTS

From Sir Julian Huxley, FRS

SIR: I am glad that the Ecologist has published *A blueprint for Survival*, and hope that its message will be widely heeded, not only by individuals, but by local councils and the government.

Having been interested in the conservation of nature and wildlife for 60 years, having helped to establish national parks both in East Africa and Britain, and having campaigned for population control for over half a century, I naturally find myself in agreement with your Blueprint and the conclusions to be drawn from it.

In those 60 years a great deal has been accomplished. Much wildlife, both plant and animals, and much glorious scenery have been saved for public enjoyment. Family planning and population control are now the concern of many governments and of the U.N. and its agencies. Britain now has a Ministry of the Environment, and most Western nations are taking steps to curb overpopulation.

Yet the situation is graver than ever, mainly because of the continued increase of the population.

Even in our little island, nearly half a million human beings are added every year. More people, more pollution, more cars, more sprawling cities, more congestion.

I hope that we shall take action, not merely against pollution, but against the unchecked increase in human numbers.

Instead of paying couples more for increased families, we should at least reduce family allowance for each child after the second. Or we could, as India has shown, reward people who allow themselves to be sterilized. Britain should formulate and implement a population policy, officially aiding family planning and advertising the dangers of further increase in numbers; the United Nations should do the same for the world, where higher rates of increase in developing countries are widening the gap between their prosperity and that of the richer nations.

We should of course take further steps to prevent haphazard invasion of what is left of our unspoilt countryside, by unregulated building, and should prohibit mining and other commercial activities in national parks and areas designated as of outstanding beauty.

Above all we should, by all means at our command, make it clear to the inhabitants of this planet, that it is urgent to reduce the increase of population.

JULIAN HUXLEY, F.R.S.

From Prof. C. H. Waddington, FRS

SIR: I think the Blueprint for Survival is quite right to argue that we cannot sustain indefinitely a policy of growth, when growth is defined in the terms such as GNP as used at present; and that the alternative must be a social system which has built into it much more stability in the form of self-correcting mechanisms, both for the system as a whole itself and for its component subsystems. However, I want to emphasize that this should not be taken as a call for a simple return to nature, a lowering of the real standard of living and a regression to less sophisticated technology. To design and put into operation self-stabilizing social and productive mechanisms will demand a deeper understand- and a more sophisticated technology, than anything we have at present. The recycling of wastes is more demanding of intellectual and practical understanding than merely throwing them away. To control pests and improve crop yields by biological control, and to find a means of improvement of yield which co-operate with, rather than merely swamp, the natural ecosystem, is a more sophisticated job than merely to poison the pests and dump fertilizer indiscriminately over the cultivated surface.

Moreover, the standard of living should be measured in real terms, which take account of the major values of life, such as happy social relations; social security; leisure, and the means to enjoy it, such as education, sport and creative activities of many kinds. It is clear that growth of these values can, and should, continue for many generations, even though in order to achieve this we may have to restrain the growth, as it is assessed today in such crude indices as the GNP.

The real message of the *Blueprint for Survival* is not back to a time which is

simpler because it is more primitive and less sophisticated': it is rather forward to a time which is simpler because it is more integrated and more sophisticated.

Yours faithfully,

PROF. C. H. WADDINGTON, CBE, FRS,
Professor of Animal Genetics, University of Edinburgh.

From Prof. D. Gabor, FRS

It so happened that I have read the leader in Nature of January 14. "The Case Against Hysteria," before your "Blueprint for Survival." Somewhat to my surprise, I could not detect in it any signs of hysteria. It is a reasoned statement of facts, of a goal whose desirability few people can dispute, and of a plan cautiously phased out over 100 years, with provisions for learning from experience. I do not agree with all its recommendations and conclusions. I would not advocate a power tax, because the increasing scarcity of high concentrates of certain rare materials will force us to use more energy for extraction, and with Alvin Weinberg I believe that atomic powerplants need not be dangerous polluters. Instead of a raw materials tax I would rather give positive incentives for recycling. I consider units of 500 people as much too small for the development of a high civilization. I would prefer to see small towns, with all cultural amenities, numbering inhabitants of the order of 50,000. But these are small differences of opinion, matters of quiet discussion.

Why then the violent backlash, which deserves the adjective hysterical far more than your "Blueprint"? The attack against the environmentalist started. I think, with Anthony Crosland's article which accused them of elitism and contrasted them with the simple people who wanted jobs, not beauty, and sunshine with fish and chips in Mallorca. Why the more recent insinuations against the Club of Rome, and the unconditional rejection, by the Establishments at both sides of the Atlantic, of the pioneer work of Jay Forrester and Dennis Meadows? I have said long ago that growth addiction was the creed of our times, but it was a surprise even to me that it had the intensity of a fanatical religion.

My advice to you is: do not respond to heated attacks with increased heat. I was very glad to see that Paul Ehrlich does not figure among your references: keep away from such doubtful allies. Let the discussion simmer down from the emotional to the intellectual level. Truth will win in the end.

DENNIS GABOR.

From Sir Geoffrey Vickers

Sir: Thank you for sending me your "Blueprint for Survival." I like this even better on second reading.

The ecological analysis is most cogent and comprehensive; you have done a most useful job in bringing all this together. I full agree with your anaylsis of the self-exciting and therefore self-limiting, if not self-destructive character of the governmental-entrepreneurial system and the economics which goes with it and supports its assumptions. I have some reservations on the social analysis. But my main criticism is that you seem to me unduly to mute, if not to misread some of the political implications.

Obviously the policy includes everything most hateful, at least in the short run, to government, business and trade unions—shrinking tax base, falling revenues, higher costs, shrinking markets, more work, lower wages, eroded differentials, lower GDP. The only current "goal" in the programme is reduced unemployment, through the encouragement of labor-intensive industry. This is important and will become more so if, as I expect the present expansive policy comes to be recognized as incompatible with other than rising unemployment. But even your promise of lower unemployment looks like being realized more slowly than the corresponding costs.

So it won't be easy to get it accepted by both political parties, industry and the trade unions. But given that you do, I ask myself, among other questions—

1. How could you implement it without starting a major recession (and having abjured in advance most of our present controls, such as they are)?

2. How, whilst implementing it, could we remain sufficiently competitive in international markets. (It would obviously be absurd to wait until everyone else has agreed, especially since many other countries can afford to wait much longer; and

3. Would fiscal measures be enough to boost labour intensive industry quickly enough, and if not, what are the alternatives and supplements?

There are answers of a sort to all these questions, though some of them would go best with Fidel Castro as prime minister and Dr. Schacht at the Treasury— I choose two names for which I have high respect—and I won't begin to elaborate. But two points seem to me to be clear; these changes postulate an ideological revolution and a strong central government.

To bring this country from its present state to a stable state, I think, require centralized control at least as strong and far more extended than in the last war. Then we had rationing of essentials, the virtual discontinuance of luxuries, direction of labour and extensive control of incomes, prices, wealth and land use. Some of these would be more, some less needed. But I see no chance that greater physical dispersal would mean greater devolution of political power. There would indeed be much for local government to do, even more than now. But the weight of decision and control at the center would surely be much increased. (How else, for example, could your prosperous local communities support the starving ones or arrange to share limited and therefore probably licensed imports?)

Such a society may be highly democratic, highly participatory and socially well-knit. It will only work—and only happen—if everyone is frightened by events and prospects into an enormously enhanced level of responsibility, which will be expressed *both* in accepting centralized control *and* in implementing it at grass roots level, as in the war farmers-implemented agricultural policy and housewives implemented rationing. And for the same reason there may well be, as there was in the war, more humanity, mutual help at the personal level, social intercourse, community spirit and mutual trust, including trust of government and its officials. But I think the paper plays down the blood, sweat, and tears to an extent which may make it (or its authors) sound a bit unrealistic.

I shall be glad to help in any way I can.

Yours sincerely,

Sir GEOFFREY VICKERS,
Little Mead, Goring-on-Thames, Reading RG8 9ED.

[From the Ecologist, April 1972]

A BLUEPRINT FOR SURVIVAL

COMMENTS

From Sir Eric Ashby, F.R.S.

SIR: The "Blueprint" contains some statements which are incorrect and some assertions which are not justified by the facts. But to dismiss the message of the "Blueprint" because of these shortcomings (deplorable though they are) would be mere pedantry. If it deserves censure over style and content, it deserves, too, the respect due to sincerity and courage.

The dispute between those who support the "Blueprint for Survival" and those who reject it is a dispute about means, not ends. Everyone who has thought about the future of the environment agrees that exponential growth of population and consumption of nonrenewable materials (like fossil fuels and metals) cannot continue indefinitely; it follows that everyone agrees that growth of these two must flatten out.

The dispute is about two issues: (a) How will this flattening out occur? and (b) How can people be made aware that it is going to occur, and adjust their values accordingly?

Those who support the "Blueprint" believe that the phase of flattening out will be accompanied by a collapse of Western society unless people deliberately and consciously revise their whole scale of values, abandon urban life, and reorganize themselves into small labor-intensive communities. The technique for achieving this end—according to these supporters is to create a state of anxiety among the public about what will happen if they do not revolutionize their style of life and reduce their consumption of goods and services.

Those who reject the "Blueprint" do not deny that this change of values will occur, but they believe that the transition will be more stable if it is not deliberately engineered (by, for example an authoritarian regime) but is left to the homeostatic mechanisms which have operated in society for thousands of years. Thus, supplies of fossil fuels will not disappear suddenly any more than supplies of timber did; their increasing scarcity will put up their cost and oblige societies to adapt their style of life to low-energy needs. Populations will not be reduced

by decree, but by the increasing difficulties of supporting large families; and so on.

The "Blueprint" calls for an orchestrated overall plan to compel people to adapt themselves to live in equilibrium with nature. Opponents of the "Blueprint" do not believe that overall plans of this kind ever have been realistic or feasible even for single nations, let alone the whole world; and they are convinced that attempts to carry out such plans, by propaganda or compulsion would fail, and leave despair and bitterness in their wake. But these opponents do not deny that change must occur. Their alternative is the prescription of William Blake (one of the pioneers of conservation); to achieve change not through sweeping rhetoric but "in minute particulars"; encouraging recycling and innovation which conserves resources, diminishing the amount of pollution per unit product, and diverting much greater technological effort from superfluous consumption to minimizing the impact of man on his environment. Both parties to the dispute are likely to agree about some of the practical measures which are needed (some device to ration scarce raw materials, for instance). The opponents of the "Blueprint" want to negotiate the transition to a steady-state economy by means of thousands of small adaptations, not necessarily articulated into one grand program. Those who support the "Blueprint" want a grand program.

Neither course will be painless. Some tragedy is—in my belief—inevitable. My preference for change through minute particulars is simply that this is the way societies have, with great benefit to the common man, adapted themselves for centuries to the consequences of their own impact on the environment. And this adaptation continues. Two centuries of careless exploitation in Britain is now being succeeded by a phase of genuine concern and massive expenditure to make amends for the past. The priorities of society are already changing. I prefer to let this process of adaptation proceed at its natural pace (with all the risks which this undoubtedly involves), rather than subscribe to a comprehensive Blueprint which—unless enforced by autocracy—is unlikely to get further than the drawing board.

Sir ERIC ASHBY, F.R.S.
Chairman, Royal Commission on Environmental Pollution.

From Rt. Rev. Hugh Montefiore

SIR: You were kind enough to show me a draft of "A Blueprint for Survival" for comment before it reached its final form: some of the comments that follow I made then, and some proceed from further reflection. I said then, and I repeat now, that I warmly welcome the whole enterprise, and I am in general agreement with its practical recommendations. Nothing that follows should overshadow this fundamental accord, both on principles and on measures that need to be taken. Of the points that I want to make, some are comparatively trivial, but others, as I believe, point to fundamental inadequacies both in the analysis and in the remedies proposed. Most of them are to be found in my Rutherford lecture. "Doom or Deliverance?" (MUP 1972) 48 p.

Mineral Resources

On page 7 of the "Blueprint" a diagram is reproduced showing mineral reserves, both static and exponential. On page 41 there is an appendix on non-renewable resources (which, strangely, excludes the good earth). No evidence is given for the statements about the mineral reserves that remain. Since diminution of resources plays a large part in the main argument of the thesis, it is essential to prove statements about mineral reserves by reference to acknowledged authorities.

Economic dislocation

The process of industrial and commercial "rationalisation" is largely responsible for the increase of unemployment in this country over the 1 million mark. A transfer from flow to stock economics is likely to cause far more dislocation. In paragraph 244 it is stated, in connection with measures proposed, that "naturally the full force of such measures could not be allowed to operate immediately: they would have to be carefully graded so as to be effective without causing unacceptable degrees of social disturbance". This vague statement needs translating into economic reality. In paragraph 267 the accusation is denied that "we are willing to bring about the collapse of industry, widespread unemployment and the loss of our export market." But I would like to hear an economist asking and answering the question. Is it possible to make this transition without great dislocation and huge unemployment? I would like to hear a politician

telling us what would be the maximum acceptable degree of social disturbance; and, most important of all, I would like to hear a political philosopher thinking aloud about the ethics involved in deliberately causing present pain and suffering and dislocation in order to promote the future well-being of future citizens.

National Imbalances

In almost all countries of the world, there is a huge imbalance between the standard of material living enjoyed by its richest and poorest citizens. This imbalance is only tolerable to the poorer citizens because of their expectation that their material standard of living will rise, and probably rise proportionately more than that of the richer citizens. If however, the predictions of the "Blueprint" are correct, there will be a ceiling to the nation's material standard of living. The section of the "Blueprint" concerned with "creating a new social system" does not so much as mention the present imbalance, nor does it contemplate any measures to redress it; yet it is likely that this would be as politically necessary as it is morally desirable.

International Imbalance

Here I can best quote from my own Rutherford Lecture: "The finiteness of our global resources and the impossibility of bringing them up to those enjoyed, say, in the Western world, raises in acute form, the question of their equitable distribution. In a situation of perpetual growth this problem is partly obscured by the rising standard of living in poor countries. Where overall growth slows down or ceases, the moral problem of the different living standards in rich and poor countries becomes even more acute. Already the difference between them is enormous, and it is growing . . . If the developing countries thought that one day they could catch up, this might be just tolerable. But now we know for certain that the world could not sustain that kind of standard of living among all its inhabitants. The case for redressing the balance is overwhelming, especially on a Christian view." ("Doom or Deliverance?" Manchester University Press 1972. p. 15ff.)

This subject surely should be a matter of major concern in "A Blueprint For Survival", but it is not mentioned.

International Agreement

The "Blueprint" assumes the inevitability of international agreement: a more realistic appraisal would view it rather as an improbability. As these words are being written, it is uncertain whether or not the Eastern bloc may withdraw from the U.N. Conference on the Human Environment this summer on account of some convention of international politics by which Eastern Germany is not yet a member of the U.N. although she will be, all being well, shortly after the conference. National loyalties and rivalries are terribly strong: and yet there must be international agreement to put the blueprint into effect, since ecological problems are world-wide, and if one country reduces its pollution, or produces (e.g.) a car suitable for leadless petrol, it will price itself out of the export market, unless others do the same. We cannot go it alone.

Regionalism

The "Blueprint" rightly stresses the need for regionalism, so that communities may be broken down into smaller more autonomous and more meaningful units. But nowhere is the contrast faced between the desire on the one hand for regionalism and the necessity on the other hand for larger units, or at least larger accord between units, in order to guarantee the right priorities in agriculture, production and pollution.

Ethical Criteria

The "Blueprint" does not raise the real ethical principles underlying the need to change our way of life. What duty do we owe to posterity and why? What right have we to use the resources of the world as we wish and when we wish? What are man's duties, other than self-interest, towards the world of nature, both organic and inorganic, living or sentient? Are its authors working on an unexpressed utilitarian ethic or what?

The Behaviourist Fallacy

The "Blueprint" tells us of many things that man ought to do, but never seems to suggest that there will be much difficulty in persuading men to do them. But man is capable of greed just as much as goodness; and he finds change

particularly difficult to absorb. Underlying the "Blueprint" is the suggestion that if only the conditions are right, if we evolve a new social system, man will behave in the kind of way that he should. This is a fallacy. Not even education is sufficient to change long inherited tendencies toward acquisitiveness and greed. What is needed is something akin to religious conversion: an emotional shock affecting the very ground of man's being, in which he finds himself responsible to one whose goodness and grace sustains the cosmos in being: a true perspective in which he sees this world not as an end in itself but in the perspective of eternity; a sense of the holiness of all created things, sustained by the "Spirit of God," so that to abuse the created order is to grieve the "Holy Spirit of God" himself. Man needs a profound inner reorientation if he is to co-operate with his environment in a new and stable kind of ecosystem. He needs to use his God-given dominion over nature is a way consonant with his nature as created in the image of God, that is to say, in a way that is divinely responsive and responsible. Without this change there can be no implementation of the "Blueprint for Survival." The present signs of coming eco-catastrophe are the outer symptoms of an inner spiritual malaise; and because the "Blueprint" misses this vital truth, it is sadly inadequate. The positive program that it puts forward is heartening and hopeful; but unless man can find the will to implement it, it will remain a mere aspiration.

The "Blueprint," in defining the goal, would do well to consider the nature of happiness and the way man can find it. Is it sufficient merely to state the goal of "providing a way of life psychologically, intellectually and esthetically more satisfying than the present one?" (paragraph 354). Or is happiness better described in the Beatitudes of Jesus?

Yours sincerely,

The Right Reverend HUGH MONTEFIORE,
Bishop of Kingston-on-Thames.

[From the Washington Post, Dec. 20, 1972]

A WORD OF WARNING

(Reviewed by Samuel Mines) [1]

"Blueprint for Survival." By the editors of *The Ecologist*: Edward Goldsmith, Robert Allen, Michael Allaby, John Davoll and Sam Lawrence.

This relatively slim volume is an impressive storehouse of information on the pragmatic aspects of the environmental situation. In short, it deals unemotionally, and in an admirably terse clipped style—wasting no words on appeals to humanity's finer instincts—with what needs to be done if we are to avoid turning the planet into a clinker.

Compressing more solid fact into every page than the vast majority of far bulkier books, this style is all the more wondrous for being a sort of committee job—the work of five editors of the British magazine, *The Ecologist*. Although based on material from the magazine, this is an American edition and readers will find many references to the American situation and very few to the British.

There are other reasons for this anyway. As the most affluent nation in the world, we use the largest share of the world's energy and resources and create the most waste; hence we are contributing most to the lifestyle which has brought us to the present brink.

If there is a lingering doubt in your mind that we are in an environmental pickle—in view of some backlash from people who should know better, yet have arisen in public print with cries that environmentalists are hysterical—"Blue print for Survival" should put that doubt to rest very nicely and provide a small clammy feeling of fear as well. I think it is the very absence of hand wringing that does it—just the cold marshaling of fact and the well-known British understatement. "If current trends are allowed to persist, the breakdown of society and the irreversible disruption of the life-support systems on this planet, possibly by the end of the century, certainly within the lifetimes of our children, are inevitable." No maybes.

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[1] The reviewer is the author of "The Last Days of Mankind."

The book is in three parts. Part 1, the program, deals with the need for change and the strategy for a stable society. Part 2 assembles in crisp review the evidence that our ecosystem is being destroyed. Part 3 contains the goal, subtitled "A Legacy of Hope." Which indicates some optimism after all, although you may be thoroughly chilled by the time you get there.

The authors' preface and the introduction by Paul Ehrlich give credit to Donella and Dennis Meadows for their Massachusetts Institute of Technology-based study, *The Limits to Growth*, published earlier this year, the first statistical paper to put a finger on the calendar and say, "This is the jumping-off place." The Meadows study, sponsored by the Club of Rome, has been wildly praised and furiously attacked, but never, to my knowledge, actually refuted. "Blueprint's" intention is to go on from where *Limits to Growth* stopped. It utilizes a lesser known but highly prestigious MIT study called SCEP—The Study of Critical Environmental Problems.

The SCEP report coined the phrase "ecological demand," which it defines as a "summation of all man's demands on the environment, such as the extraction of resources and the return of wastes." The most convenient measure of ecological demand is the gross domestic product (GDP), or population multiplied by the material standard of living. According to the United Nations Statistical Yearbook for 1968, GDP is increasing annually by 5 or 6 percent, doubling every 13.5 years.

Population is increasing worldwide by 2 percent a year, adding 72 million annually to the current 3.6 billion. However, in undeveloped countries, which contain two-thirds of the world's population, the growth rate is higher, between 2 and 3 percent, and nearly half the population is under 15. Even if the birth rate drops to the replacement level by the year 2000 in the developed world, and by 2040 in the developing world, population will stabilize itself about 100 years from now at nearly 15.5 billion, or more than four times the present size. Meanwhile, with the United States alone aiming at a growth rate of 4 percent in gross national product, the implication of disaster is unavoidable.

The real villain is exponential growth, the darling of the chambers of commerce, and which MIT Prof. Jay Forrester labels "treacherous and misleading." As an example: if our total world reserves of petroleum are 2,100 billion barrels and our rate of consumption is increasing by 6.9 percent a year, by 1975 we would have used only 12.5 percent of the supply and could easily be lulled into a false sense of security. But only 15 years later we would reach the jumping-off point; demand would have exceeded supply.

There is an old story illustrating the treachery of exponential growth which concerns itself with lily pads in a pond. If the pads double their coverage each day and a calculation shows that they would take 30 days to fill the pond, as late as the 29th day the pond would still be only half full. The situation would hardly appear extreme. Yet one more day and it is all over.

This is the crisis of the environment. It won't look bad until it is all over.

The trouble with the exponents of growth is that they visualize a world of 15 billion people all with the same material standard of living as the United States. Actually, even the United States cannot afford its present standard without milking the rest of the world.

Having hammered home the central message and buttressed it with fact and figure, "Blueprint" turns to the plan for a stable society. The principal conditions of a stable society, or one that can be maintained indefinitely, are minimum disruption of ecological processes; maximum conservation of materials and energy; zero population growth; and a new social system in which the individual can enjoy, rather than feel restricted by, the preceding conditions.

The necessary changes may occur through seven operations:

a control operation to reduce environmental disruption by technical means;

a freeze operation to halt present trends;

an asystemic substitution of less dangerous procedures for present dangerous ones;

a systemic substitution by which the technical substitutions are themselves replaced by "natural" or self-regulating ones;

the discovery of alternative technologies to conserve energy and materials;

decentralization of the economy and polity with the formation of many small communities rather than a few large ones;

education for such communities.

The calm assumption that all this must and should be done is undoubtedly enough to make engineers, industrialists, and urban planners go bananas. Replace our present huge metropolitan centers by many small communities? How? Retrain millions of people in new kinds of work? Bring back the small family farm when the trend is all in the opposite direction and the small farmer is succumbing to the mechanized, computerized syndicate farms?

"Blueprint" acknowledges that the shift to small communities is the most radical change proposed in the book and this is an understatement, British or any other kind. It is a change, I am inclined to think, which could only happen as a result of complete breakdown of the present system, or a devastating holocaust like a nuclear war. In that case there might be a few small communities left, to start over, or there might not. What particular cataclysm the authors expect to provide the impetus toward decentralization they do not say, but they insist that small communities are the only ones in which internal or systemic controls are most likely to operate effectively.

The quarrel here is between the pragmatists who say this is utopian nonsense and the ecologists who say utopia it may be, but any other course is suicide, so where's the choice?

A book as tightly organized as "Blueprint" and so crammed with solid, close-knit reasoning is impossible to dissect and to describe with enough examples to give something of its flavor. There is just too much. The temptation to quote arises on every page and would lead in the end to quoting the entire work.

If the environment problem disturbs and concerns you, if you are not pacified by the backlash arguments, or by those who insist that conservationists must come up with viable alternatives if their warnings are to be seriously considered, this is your book. It will, at least, provide ample ammunition for the inevitable arguments about the imminence of doomsday.

How To Live With Economic Growth

(Some safety devices to ward off doomsday by Henry C. Wallich)

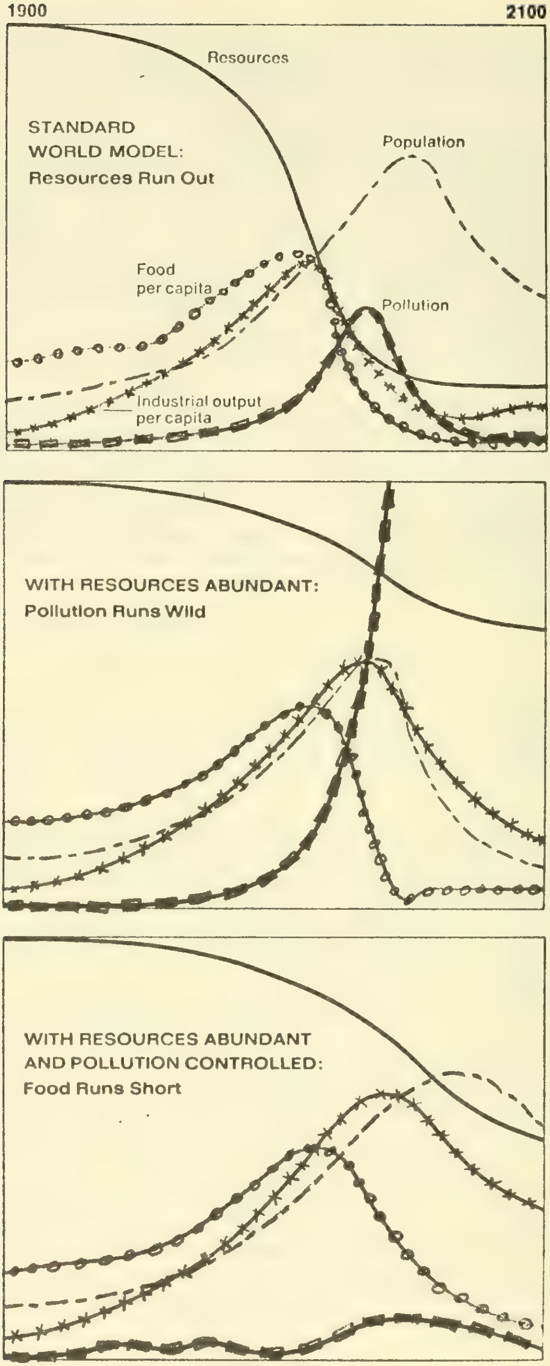
Almost suddenly, it seems, the once positive word "growth" has taken on dark, disturbing connotations. Various voices, some of them hard to ignore, have warned us that continued worldwide growth will lead to a hell of degradation and collapse.

Such a warning was sounded early this year in *The Limits to Growth*, by a team of systems analysts at M.I.T. The authors used a computer model of the "world system" to trace out alternative futures under various assumptions. Three of the scenarios, all grim, are represented in the charts at the right. In the second and third charts, it is assumed that virtually unlimited nuclear power greatly increases available resources. (Since the five variables in each chart are measured in different units, no significance should be read into the height of one curve relative to another curve in the same chart.)

Computer modeling of this kind lends an air of rigor and precision to projections that actually involve far from rigorous suppositions. But it would be unwise to disregard the findings on the account. The soft pudding of suppositions encloses a steely core of truth. The earth is finite, and therefore the growth of both population and physical output must eventually cease.

The policy implications, however, are far from clear. Despite the precision of the computer tracings, there is uncertainty about timespans. What's more, cooperative global action to suppress growth cannot be considered a real possibility. And in a still-growing world it is very hard to make a case that zero economic growth is the best policy for any particular society.

In this article, economist Henry C. Wallich of Yale University maps a course between do-nothing and stop-everything. A former member of the Council of Economic Advisers, Professor Wallich argues that, if we let it work, the price system can provide powerful safeguards against the hazards of growth. Fortunately, the measures he advocates would also help protect the qualify of life here and now—a bit of cheer in an area that can certainly use some.


1900
2100
Resources
STANDARD
WORLD MODEL:
Resources Run Out
Population
Food
per capita
Pollution
Industrial output
per capita
WITH RESOURCES ABUNDANT:
Pollution Runs Wild
WITH RESOURCES ABUNDANT
AND POLLUTION CONTROLLED:
Food Runs Short

The recent warnings about the risks of growth present a troubling dilemma. Are the risks so grave that we must stop growing in the near future? Should we ignore the risks, on the assumption that the ecologists have vastly exaggerated them? Given the stakes, the choice looks awesome. Fortunately, there is a way of avoiding the need to make the choice.

The prospects of running out of food, living space, or raw materials, of suffocating or collapsing by one computerized sequence or another, can be debated till doomsday, whenever that may be. Rather than accept an answer that may be wrong or inconclusive, we can guard against the harmful effects of economic growth by installing appropriate safety devices. If the critics of growth are right in thinking that ultimate limits are only a few generations away (to me this seems unlikely), these safety devices would slow the economic system in the near future and bring it to a halt in good time. If the critics are wrong, the devices will not impede growth, but will monitor the economy for adverse effects of growth.

The safety devices I have in mind take the form of an extended version of the price system. The price system can be made to function as an automatic pilot, or sensor for an emergency brake, that will stop growth when the costs become too high.

THE ROAD TO A STANDSTILL

An enterprise grows so long as it can produce goods for less than it sells them for. It will have a positive return on capital and will continue to invest in plant and equipment. If costs rise to the point where expansion does not pay, the return on capital vanishes, investment stops, and the enterprise ceases to grow.

By generating these simple cases, economists many years ago arrived at a model of the "stationary state." This is the economy that has ceased to grow, where the processes of production and consumption repeat themselves year after year within significant change. The stationary state is not the implausible construction of some lonely imagination. It is the logical end product of a process in which enterprises keep endowing each worker with a greater and greater volume of tools. The law of diminishing returns then sees to it that investment earnings gradually decline. When returns to capital have come to an end, a state of zero growth begins.

WHO PAYS FOR DEGRADATION?

The faster costs increase, the faster returns on capital diminish. If an enterprise has to invest heavily in pollution-abating equipment, if it has to pay more for increasingly scarce raw materials and increasingly costly land, the point of zero return approaches rapidly. But if research and development succeed in pushing that point into the future, growth continues.

If, therefore, we are concerned about the dangers of growth, we should let these dangers find expression in costs. This is the principle of internalizing the "externalities"—the pollution and other costs of growth that are now borne by the community. Degradation of air, water, or land rests lightly upon the company that does not have to pay for it. It rests lightly, too, upon the consumer of the company's products if he is not charged for the environmental costs.

Concern over such externalities has increased as the environment's capacity to diffuse them has diminished. Critics of the free-enterprise system have found externalities a welcome addition to their repertory of proofs that the market system is defective. They are right in demanding that these costs be taken into account in deciding what should be produced, and in what ways. But their indictment of the price system backfires, because further examination reveals that the best way of internalizing environmental costs is precisely to apply the price system.

The simple-minded reaction to the affront of pollution is to prohibit it. No need then to bother with internalizing environmental costs. The difficulty with this approach is that it sets up all the wrong motivations and is inefficient to boot. Confronted with edicts and regulations, polluters, have every reason to prove that they cannot help what they are doing. Different polluters find that their costs of abatement differ unfairly and uneconomically. Perfection, moreover, is inordinately expensive. I doubt very much that many people would be willing to pay what it would cost to restore the waters around Manhattan to the condition in which Henry Hudson found them.

LICENSE TO POLLUTE

The price system sets up the right motivations. Let people pollute, but let them pay for it. Environmentalists' indignation about "licenses to pollute" is misplaced. The price of a license can be set at any level, and it can be set high enough to achieve any standard of cleanliness that is wanted. Given the cost, the polluter then has a full range of choices—pollute and pay, stop polluting by stopping production, invest in antipollution equipment, change his production process, his product, his location. Each polluter, in other words, can work out his own optimum response, depending on his circumstances. This freedom to optimize makes for equity and efficiency.

Setting the right level of tax or fee will present some difficulties, to be sure. For one thing, the response of the polluters to any particular level cannot be predicted with certainty. To the economist, the logical approach would be to set the permissible level of emissions, discharges, and other damages and then auction off licenses to pollute to the highest bidders. Those who find pollution the cheapest of all available alternatives will pay what it takes to get the licenses they need. The rest will reform in some manner. But setting fixed prices on pollution, through a trial-and-error process, will accomplish the same results in time.

If the level of pollution is to be kept constant, standards of cleanliness will have to rise as the economy grows. The process of cleaning up is an unending race between the number of sources of pollution and the reduction in pollution per source. Since costs accelerate as 100 percent purity is approached, the outcome of this race has much to do with how far growth can go.

Business spokesmen often argue that subsidies of some sort, such as tax credits or easy financing for antipollution equipment, would be a more promising approach than taxation. And according to a respectable theorem of economics, a tax and a subsidy, both designed to encourage cutbacks of production that pollutes, will have equivalent effects on the level of output. (To the polluter who does not cut back, the loss of the subsidy is the same as a tax.) But in the long-run the effects are not the same: a tax tends to drive companies out of the industry, a subsidy tends to attract them.

Subsidies of particular forms of pollution control, moreover, tend to restrict the scope of the polluters' search for alternative solutions. A tax credit for antipollution equipment, for instance, does nothing to encourage shifts to nonpolluting processes. Nor does it offer an incentive to keep the equipment operating once it has been installed. Since the costs of operation often are considerable, the results of a subsidy system might disappoint its advocates. On the other hand, tax credits for general R. & D. would not interfere with flexibility of business response.

CHANGING THE OUTPUT MENU

For the sake of both fairness and efficiency, it is important to tax the pollution and not the product. This is the answer to the demand that the Government intervene on a grand scale to revise the output menu. In the view of those who favor such intervention, one way to defuse the dangers of growth is to shift toward forms of output that throw off less pollution and make fewer demands on natural resources. From this viewpoint, big artifacts are worse than small. Fashion products are worse than indestructibles. Advertising that increases consumer demands is bad altogether. Work generating income and output is worse than leisure.

Such conclusions involve vast oversimplification. Big cars can be made to pollute less than small (and to be safer). Big objects made of plastic may require less use of scarce resources than smaller objects made of metal. Advertising may promote environmentally sound goods and services. Built-in obsolescence may encourage innovation.

Taxing pollution rather than products allows freedom for all this. In a very broad sense, however, pollution taxes will tend to shift the structure of output toward its low-pollution components.

Any method of internalizing external costs will require some intervention by the political process. Decisions have to be made about admissible levels of pollution and of resource use. The minority that is outvoted by the majority must accept something it does not want—for example, cars that are more expensive, or less efficient, than the market would have produced if left to its own devices. The sweet free-market simplicity of voting with dollars will have been adulterated. But the environmental imperative will have been dealt with at the least possible cost.

The political process can serve to backstop internalization in still another way. To make people pay for the damage they do is the efficient way, but it is also sophisticated, and it will not always have adequate political support. To rally that support, some measure of direct intervention, through regulations, controls, and prohibitions, will probably be needed. These techniques, moreover, may have marginal advantages in cases where fine tuning of the constraints on pollution is called for. Pollution taxes should cut evenly across the board, the fewer exemptions the better, but evenness may entail some unfairness in special circumstances. Detailed regulation can provide relief from special-case hardship.

VIRTUES IN HIGHER PRICES

The reason we have only recently become aware of the need to internalize environmental damage is that until recently it was not necessary to regard air, water, and waste-disposal sites as scarce resources. Their use, or misuse, did not have to be paid for, and therefore did not enter into business cost calculations. On the other hand, scarce natural resources such as raw materials and fuels have always been internal to business cost calculations. Accordingly, one is tempted to assume that the price system can and will take care of the danger of "running out of natural resources," which plays such a prominent part in doomsday theology.

To deal with resource shortages, the price system can activate an impressive array of mechanisms. When some resource becomes more and more scarce, say copper ore, its price rises and the system responds. The working of lower grade ores now becomes economically feasible. Search for new ore bodies becomes profitable. So does recycling, as well as substitution of other metals, and the application of research to all these techniques. Where none of these alternatives avails, products containing copper will become more expensive and demand for them will decrease.

How well these processes work depends in large measure on how well the supply and the demand respond to price. It depends also on what economists call the elasticity of substitution—that is, the extent to which a relative increase in the price of copper turns users to substitutes.

In a long view, the working of the adjustment processes also depends on how far the price system is able to look ahead. The threat of a coming shortage of a metal or mineral should be reflected in its price. The increase in price would activate response mechanisms and give them the long lead they sometimes need.

We know, of course, that the prices of most natural resources today do not reflect expectations of future shortages. The historical evidence, indeed, tells us that the cost of most natural resources has been declining in terms of the capital and labor required to make them available. Past predictions of shortages and steep price increases have so far proved erroneous. Numerous studies of future resource needs and availabilities envision no general shortages for the next 50 years. (See the article on page 109.)

It is unsurprising, therefore, that prices of raw materials today do not reflect future shortages. Nevertheless, we cannot be sure whether, given the prospect of shortages at some future time, the price system would in fact respond with sufficient foresight.

THE LOW VALUE OF THE FUTURE

Various factors besides human fallibility suggest that it might not. To invest today in resources to be marketed many years later is a risky business. New technologies, new discoveries, shifts in demand may upset the estimates. A corporation holding potential output off the market in expectation of higher prices in the distanct future would be exposed to risks of adverse taxation, expropriation, and other acts of God and man. Discounted at high interest rates, in any event, the present value of the future is not very high. All this offers a presumption, at least, that the price system may be slow in responding to threatened resource scarcities in the future.

This presumption may not be strong enough to call for large-scale Government action to conserve resources across the board. A "raw-materials tax," such as that recently proposed by some British environmentalists, would be an assault on the economies of the developing countries, with minimal justification in the existing supply situation. But if the visible picture should change, a resource tax might serve to strengthen the price system for its job of conserving resources. It would contribute to internalizing the resource-depletion cost of growth, just as pollution taxes internalize the pollution cost.

For the time being, all that seems needed is to put an end to some Government policies that are positively hostile to good resource management. The political bias is usually on the side of lower resource prices. In the field of public-utility regulation, this bias has been broadly appropriate because Government action has been directed toward preventing the exploitation of monopoly. Cost is the proper basis for public control of utility rates. But Government commits an elementary error when—as in the case of natural gas regulation—it applies cost reasoning to a price that really reflects scarcity rather than monopoly. The natural gas shortage is now demonstrating the consequences of not allowing the price system to do its job. And the recent decision of the Federal Power Commission to permit a little slack in the regulatory leash may be a sign of incipient wisdom.

The oil-depletion allowance, like capital-gains treatment for timber and certain minerals, occupies an ambiguous spot in the resource-conservation picture. If one anticipates a future shortage, it makes good sense to encourage the search for oil. But it does not make good sense to encourage heavy use of oil. What seems called for is a policy that encourages creation of reserves while discouraging use. Heavy current use seems appropriate only if one expects new sources of power to make oil obsolete before most of it is out of the ground, a fate more likely to befall coal than oil.

Examples of bad resource policy abound. The Government encourages possible overuse by the way in which it sells or leases mineral rights. It discourages recycling of materials by maintaining special low freight rates for lumber and minerals. Its stockpile program, national security aspects aside, tends to reflect the needs of the moment more than those of the long-run future.

A constructive public policy toward R. & D., public and private, would be part of good resource management. In the field of natural resources even more than in the field of pollution, research is needed to aid the price system in promoting the right kinds of adjustments and substitutions. A well-meaning Government will be subject to temptation to support research only in particular fields and for particular purposes. Given the unpredictable nature of much research, and the tendency for findings in widely different areas to interact, this temptation should be resisted.

CROWDED CITIES, EMPTY SPACES

The economics and politics of land represent a special aspect of the natural-resource problem. Land is broadly fixed in supply, assuming we do not plan to go underground or build a second floor over the United States. Here again, the price system does not offer complete assurance of being able to take care of the situation.

As people move into an urban area, real estate prices and rents go up. Those who do not want to pay the price can move elsewhere. So can those who feel asphyxiated by the congestion. But there is something unsatisfactory about a system that imposes added costs upon a large number of people to satisfy the preference of one individual—in this case, a preference for city life, or for the higher pay available in cities. In most other market situation where the added demand of one person raises the price to all, the higher price calls forth a larger supply. In the case of city land, however, the supply does not increase as rents rise.

A good deal of evidence has accumulated that the price system, if not intrinsically inappropriate, is at least substantially inefficient in dealing with regional crowding. It appears that population movement responds to rising rents and rising congestion only with very long time lags. To some extent these costs of urban living are offset by higher pay. Discrimination, moreover, keeps some blacks who would like to move out of cities from doing so. Accordingly, a public policy with respect to urban crowding seems to be called for. It should involve nothing so repugnant as constraint on the freedom of people to move where they like. But the tax system, the credit system, and farm price supports could well be organized more effectively to induce larger numbers of people to live in the great empty spaces of this country.

ACTIVATING THE BRAKES

The measures I have proposed in the areas of environmental protection, natural-resource management, and land use will not produce an appreciable slowing in the rate of economic growth so long as the costs of growth remain moderate. But I could be wrong in believing that the costs of growth will not increase rapidly in years ahead. If pollution becomes very hard to control, if resources do run out and substitutes cannot be found, if the problems of congestion prove resistant to limited interventions, costs could climb to prohibitive levels.

If they were internalized, high costs would activate the brakes that the price system builds into the economy. Investment would decline as its returns diminish. Growth would slow down and perhaps eventually come to a halt.

The declining rate of return would reduce the income of owners of capital. The distribution of income would become much more even. This is an important part of the slowing down process. Without growth, it would be much more difficult for democratic societies to justify large inequalities of income. Opposition to inequality would no longer be moderated by the general upward movement of incomes, and the high degree of social mobility that growth makes possible.

Because the supply is fixed, ownership of land would present an exception to the rule of declining returns on capital. Rents would rise, and the value of land would rise enormously as interest rates fell. Public policy, through appropriate taxation, would have to extend the evening up process to land ownership.

A growthless state, in the unlikely event it were reached, would leave many problems unsolved. We do not known how a society like ours would take to it. At present, Americans are not satisfied with the results of the stably rising prosperity over the last 25 years, as inflationary wage demands attest. How will people behave when their standards of consumption no longer increase? We do not know how the economy will function at a zero return on capital. Full employment can be maintained only if the Government uses, for nongrowth expenditures, such savings as people still want to set aside—savings for which there will be little demand, since borrowed capital will provide no return. An economy based on free markets still seems possible, but the fate of private enterprise becomes obscure.

Any commentary on zero economic growth should add that attainment of a stationary state by the U.S. economy would not do much to solve the growth problems in the rest of the world. Growth-slowing processes will be at work elsewhere, of course, and ultimately there may be a worldwide cessation of economic growth; but that presupposes, above all, an end to population growth. While low birth-rate patterns already prevail in the industrial countries, the less developed countries have further to go in their population cycle. There are reasons to believe that they may complete the evolution to very low birth rates faster than the industrial countries did, but there is no assurance that this will prove to be so. For people concerned about the long-range consequences of continued growth, the core of the problem surely is the expanding population of the less developed countries.

As for the United States, it has in a sense already completed the evolution to zero population growth. Births still exceed deaths, but this is a detail that reflects the age structure of the population. The total fertility rate has now fallen below he critical replacement level of 2.11 children per woman, which would bring about zero population growth in the first half of the next century.

DEFEATIST "REALISM"

Anyone aware of the stir created by the zero-population-growth movement in the last few years might suppose that the virtual attainment of ZPG in the United States would bring solutions to serious environmental problems within view. Unfortunately, this is not the case. ZPG is not in itself an effective remedy for environmental problems. It does not end crowding because a constant number of people can still dispose themselves in congested patterns. It does not help much with pollution or resource exhaustion, because the per capita income of a stationary population grows faster than that of an expanding population.

As must be abundantly clear by now, I am not an enthusiast for zero economic growth either. In a finite world, to be sure, growth cannot continue indefinitely. But advocates of zero economic growth would guard against the risks and penalties of growth by prematurely denying society the benefits of growth.

At this chapter in the human story, it makes much more sense to accept the benefits but adopt protective measures. If they work properly, undesirable effects of growth will induce feedback that slows or halts the particular kinds of growth producing those effects.

This approach to the monitoring and control of growth, moreover, will tend to improve the allocation of resources and protect the environment, whether growth is affected or not. When factories have to pay for polluting waterways, they will do less polluting. Those who tell us that if we want growth we have to put up with its stinks, noises, eyesores, and poisons are sometimes credited with realism, but their attitude might better be called defeatist. There is no inherent reason why rising standards of consumption must be accompanied by declining quality of life.

Coming to Terms with Growth and the Environment

WALTER W. HELLER

A conference of ecologists and environmentalists, economists and technologists—convened to illuminate the complex interplay of energy, economic growth, and the environment—should open, not with a declaration of war or of conflicting faiths, but with a declaration of humility. Conceptually, to be sure, we know quite a lot about this interplay—about the *processes* of resource use and disposal that overload and degrade our natural environment; about the chilling *possibility* that untrammeled growth and uncontrolled technology could eventually destroy the ecosystem that sustains us; about the *methods*, both economic and technological, by which man can arrest or reverse the march to environmental ruin; and about the *directions of changes* in priorities and institutions needed to put these methods to work.

But empirically, we really know very little. In trying to determine the causal relationship, assess the trade-offs, and strike a reasoned cost-benefit balance between economic growth and environmental integrity, we constantly run into the unknown or unknowable (or even the unthinkable), into the unmeasured or

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unmeasurable (or even the infinite). Not surprisingly, then, much of what we "know," much of the evidence, is fragmentary and inconclusive. More disconcertingly, the findings are often contradictory. A case in point: qualified and concerned analysts of the energy-growth-environment linkage have arrived at radically different assessments of future shock to the environment—almost a "no-big-deal" versus a "crime-against-humanity" split on the projected impact of energy growth on the environment by the year 2000.

Humility should lead us, then, to acknowledge and define our collective ignorance, as well as our sparse knowledge, with two purposes in mind:

1. Identifying our joint research needs and priorities.
2. Shaping our responses to clear and present environmental dangers in light of that ignorance, i.e., pursuing courses of action that permit flexible and automatic adjustment to new information, new techniques, new values, and new resource parameters.[1]

But humility in the context of this forum calls for more. It demands a sensitivity in one discipline to the concepts, concerns, and convictions in another. Lest anyone fear, however, that I am about to submerge controversy in a sea of humility, let me reassure you. Let me set the framework for my further discussion in terms of the apparent differences in perception between ecologists and economists that have to be narrowed or reconciled if we are to make a productive joint attack on the growth-energy-environment problem. At many points, as you will see, I humbly beg to differ.

First, in starkest terms, the ecologist lays down an environmental imperative that requires an end to economic growth—or sharp curtailment of it—as the price of biological survival.[2] The economist counters with a socioeconomic imperative. that requires the continuation of growth as the price of social survival. Some ecologists see the arresting of growth as a necessary, though not sufficient, condition for saving the ecosystem. The economist sees growth as a necessary, though not sufficient, condition for social progress and stability. To focus differences even more sharply, the economist tends to regard the *structure* rather than the *fact* of growth as the root of environmental evil and indeed views growth itself as one of the prerequisites to success in restoring the environment.

[1] After writing this, I encountered something in much the same vein in the introductory comments in the October 1970 *Bulletin of the Atomic Scientists* concerning the summary of the Massachusetts Institute of Technology Study of Critical Environmental Problems (SCEP): "One of the striking aspects of SCEP is its humility. It does not attempt to ring the doomsday bell. Rather, it stands as a sober, reflective, and careful statement of what man knows about the effects of these pollutants [carbon dioxide, sulfur dioxide, oxides of nitrogen, chlorinated hydrocarbons, other hydrocarbons, heavy metals, and oil] on the environment and what he has yet to learn. . . . It goes on to suggest what man can do about the problems he does understand and how he can acquire essential information about those he doesn't." The SCEP approach commends itself to this forum.

[2] I use the term "ecologist" here, not in the technical sense of a natural-systems biologist, but as a proxy for "noneconomist environmentalists."

Second, the ecologist counters that the Great God Growth has feet of clay. In his view, if we counted the full costs of water, air, land, visual, and noise pollution—i.e., the drawing down of our environmental capital—the advance of measured gross national product (GNP) in the past quarter-century might well turn out to be an illusion. In responding, the economist is at pains to make clear that he is anything but Mecca-nistic about GNP. He is under no illusion that GNP is an index of social welfare (or, for that matter, that it is even feasible to construct a single index of welfare, or that greater material welfare is a guarantee of greater happiness). But he does believe that a careful reading of economic and social data yields persuasive evidence that real GNP per capita *has* advanced even after adjusting for increases in population, prices, and pollution; and that a rise in social welfare has accompanied the rise in output of goods and services.

Third, in a very real sense, the most vexing difference between ecologists and economists may not be in their conflicting interpretations of the evidence but in their divergent modes of thinking. At the risk of exaggerating a bit for emphasis, I perceive the dedicated environmentalist as thinking in terms of exponential rates of deterioration, thresholds, flash points, and of absolute limits to be dealt with by absolute bans. (And I confess to a bit of absolutism myself when it comes to roads in the North Cascades, oil exploration in Puget Sound, and 70,000 tons a day of taconite tailings dumped into Lake Superior.)

In basic approach, the economist could hardly agree less. He thinks in terms of marginalism, trade-offs, and a careful cost-benefit calculus—not marginalism in the sense of minor adjustments but in the sense of balancing costs and benefits at the margin. As he sees it, the right solution in striking a balance between nature and man, between environment and growth, and between technology and ecology, would be the one that pushes depollution to, but not beyond, the point where the costs—the forgone satisfactions of a greater supply of additional goods and services—just equal the benefits—the gained satisfactions of clear air, water, landscape, and sound waves. What the economist regards as rational is to seek, not total or *maximum* cleansing of the environment—prohibitions tend to be prohibitively expensive—but an *optimum* arising out of a careful matching of the "bads" that we overcome and the "goods" that we forgo in the process.

Fourth, when economists and ecologists turn to the search for solutions, they find a considerable area of agreement. They would agree, for example, that where the trade-off is between today's "goods" and tomorrow's "bads," government has to step in to enforce a rational calculus. Indeed, many environmental problems can be handled only by government prohibitions and regulations (mercury and DDT come to mind) and by public expenditures for collective sewage disposal, land reclamation, and environmental clean-up. They can also join in identifying the essentially costless changes that serve growth and the environment simultaneously, thus requiring no trade-offs. One thinks, for example, of technological advances that have substituted coal and oil for wood as energy sources (the per capita consumption of timber in the United States was no

higher in 1968 than thirty years earlier) and have enabled us to reduce both costs and diesel engine pollution by moving oil and coal by pipeline rather than rail. And one looks forward to the day when thermal byproducts of energy production can be converted from pollutants to a productive source of space heating and cooling for industrial, commercial, and apartment buildings.

But where hard choices will have to be made, the economist wants to put as much of the load on the price system as it can efficiently carry. His main device would be to put price tags—for example, in the form of effluent fees or pollution permits or refundable materials fees—on the now largely free use of air, water, and land areas as dumping grounds for industrial and commercial wastes. The environmentalist's instinct is to recoil against this "license to pollute." By the same reasoning, perhaps, he feels way down deep that to let mineral resources and fossil fuels be managed through the pricing system constitutes a "license to exploit" the biosphere, a license that should be revoked or subjected to tighter regulation. But the economist wants to spread the net of the pricing mechanism widely to capitalize on its automaticity in digesting information and responding to it, its ability to integrate a vast range of decisions, its stimulus to natural resource conservation, and its lowering of demands on the government bureaucracy. His goal, of course, is not to collect fees or taxes but to build enough economic incentives into the market system to bring pollution to bay.

THE ROLE OF ECONOMIC GROWTH

Turning to the first of these four issues, one should keep in mind that the growth-versus-environment contest is in one sense a mismatch: economic growth is a means, an instrumental goal, while environmental quality is an end in itself, an important component of the quality of existence. In assessing the instrumental goal of growth, we need to inquire:

1. Whether it is growth itself, or its particular forms, that lead to environmental trouble (and if the latter, how production and technology can be redirected into environmentally more tolerable channels).
2. What social costs the nation would incur in giving up growth.
3. Whether the war on pollution could, as a practical matter, be pressed and won without growth.

Can Growth Be Stopped?

To discuss the benefits of growth in the context of environmental quality implies, first, that a realistic option exists—one that is conceptually and institutionally possible—of stopping growth or slowing it to a crawl and, second, that there is a trade-off, an inverse relation, between the rate of economic growth and the quality of the natural environment.

Whether no-growth is a conceivable alternative depends first on the nature of the growth process and the sources of growth.[3] Growth of the U.S. economy in the basic sense of growth of output per capita is anchored in (1) increases in the stock of human capital through investments in education, training, and experience; (2) increases in the stock of nonhuman capital through investment in equipment, machinery, and plant; and (3) improvements in the state of U.S. scientific and managerial technology through investments in research and development, better management and organization, and more efficient production techniques. The deepest wellspring–the "major permissive source," as Simon Kuznets puts it–of modern economic growth is the advance of technology in its broadest economic sense, that is, the advance of knowledge.

Considering man's unquenchable thirst for understanding through better education and his enduring quest for increased knowledge and easier ways of doing things–through research and development, large-scale experimentation, and small-scale tinkering–one can only conclude that growth in output per man-hour cannot be stopped. Conceivably, total output could be held in check by highly restrictive taxes and tight monetary policy or by direct controls. Since output per man-hour would continue to rise, stopping total growth would require a rapid decline in the average workweek–one calculation puts it at twenty-six hours by 1980–and a corresponding increase in leisure and nonmarket activity. (My secretary asks, "What's so bad about *that*?") This appraisal recognizes also that the labor force would continue to grow. Even with a zero population growth policy, it would take several decades to stabilize the population.[4]

[3] For an authoritative and detailed examination of this subject, see Edward F. Denison, *The Sources of Economic Growth in the United States and the Alternatives before Us* (Committee for Economic Development, 1962), and Denison's *Why Growth Rates Differ* (Brookings Institution, 1967).

[4] In *Economic Report of the President, February 1970*, p. 110, the Council of Economic Advisers reported that because of the high proportion of young people in the population, cutting the fertility rate to a level consistent with zero population growth would not stabilize the U.S. population until 2037 (at 276 million). Recent studies and new fertility data strongly suggest that, barring a reversal of present trends, the United States is already well on its way toward the desired slowdown or even stabilization of population growth. In a recent analysis, Glen G. Cain concluded that "the widely-discussed issue of the threat of the U.S. population bomb is . . . a non-issue." ("Issues in the Economics of a Population Policy for the United States," a discussion paper of the Institute for Research on Poverty, University of Wisconsin, 1971.) In the context of the RFF forum, it should also be noted that other new studies warn us that a slowdown or cessation of population growth won't solve as much of the environmental problem as we might hope. Ansley J. Coale, for example, stated, "There is no doubt that slower population growth would make it easier to improve our environment, but not much easier." ("Man and His Environment," *Science*, vol. 170, no. 3954 [October 9, 1970]). Herman B. Miller, Chief of the Population Division of the Bureau of the Census, is more specific: "Two-thirds of the rise in expenditure for goods and services would take place even if our population stopped growing tomorrow but continued to increase its income and spend its money in the same old way." (*New York Times*, February 19, 1971.)

The point of a no-growth policy would be to check and reverse the erosion of the environment. But there is nothing inherent in a no-growth economy that would change our polluting ways. So one has to posit active and costly steps to restore and protect the environment. This would require an absolute reduction in material living standards, as conventionally measured, in exchange for a more livable natural environment.

Just to sketch this picture is to raise serious questions of its social, political, and economic feasibility. Short of a believable threat of human extinction, it is hard to imagine that the public would accept the tight controls, lowered material living standards, and large income transfers required to create and manage a stationary state. Whether the necessary shifts could be accomplished without vast unemployment and economic dislocation is another question. The shift to a no-growth state of being might even throw the fragile ecology of our economic system so out of kilter as to threaten its breakdown. Having said this, let me quickly add that if the human race were to discover that it would be committing suicide unless it reduced its standard of living (at least for its affluent people), I dare say it would develop ways of managing the economic system to accommodate this necessity. Short of dire threats, however, economic growth seems destined to continue. To cope with growing contamination of the environment, the United States is thus driven to a redirection of growth and technology and to a reordering of priorities in the uses of growth.

The Growth-Ecology Trade-Off

But this still does not resolve the question of whether national policymakers should continue to stimulate growth or should seek consciously to retard it. That depends not just on the benefits of growth, which I will discuss in a moment, but on its environmental costs, on the growth-ecology trade-off. To the question of how much growth may have to be given up to protect the natural environment and maintain a habitable planet, both ecologists and economists offer a wide range of answers.

Among those who focus on global environmental problems, the spectrum runs from those who are persuaded that global pollution puts life on this planet in jeopardy to those who conclude that no one knows enough to answer the question. So far as I know, the category of ecologists (or economists, for that matter) who hold a "no-problem" view of this matter is an empty box. In its significant but selective survey, the group for the Study of Critical Environmental Problems (SCEP) offered some reassurance on the climatic effects of growth in output and fossil fuel energy but called for prompt counteraction to the ravages of toxic pesticides and heavy metals and excessive nutrient run-offs.[5]

[5]The SCEP group concluded, for example, that "the probability of direct climate change in this century resulting from CO_2 is small," though its long-term consequences

Among economists there are those who accept the "spaceship earth" concept of finite limits to the assimilative capacity of the environment and who believe that growth will test those limits within relevant time horizons and must therefore be retarded. But a majority of the economics profession lean toward the findings of a recent econometric probe of this problem by William Nordhaus and James Tobin.

1. With respect to appropriable resources like minerals and fossil fuels, which the market already treats as economic goods, the Nordhaus-Tobin estimates show "little reason to worry about the exhaustion of resources." As in the past, rising prices of fossil fuels are expected to provide strong incentives for conserving supplies and developing substitute materials and processes.
2. For nonappropriable resources, for "public goods" like air and water, they see the problem of abuse as much more serious. But the environmental disturbance and misdirection of resources that result from treating public natural resources as if they were free goods could, they believe, be corrected by charging for them. "The misdirection is due to a defect in the pricing system—a serious but by no means irreparable defect and one which would in any case be present in a stationary economy."
3. With respect to global ecological collapse, they appropriately conclude that "there is probably very little that economists can say."[6]

The issue is far from resolved. But the evidence to date supports the view that it is less the *fact* of growth than the *manner* of growth and the *uses* made of growth that lie at the bottom of U.S. environmental troubles. And elusive as a consensus on the basic growth-environment trade-offs may be, it appears that a

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might be large. With respect to particulate matter, SCEP found that "the area of greatest uncertainty in connection with the effects of particles on the heat balance of the atmosphere is our current lack of knowledge of their optical properties in scattering or absorbing radiation from the sun or the earth." On thermal pollution: "Although by the year 2000 global thermal power output may be as much as six times the present level, we do not expect it to affect global climate," but they noted that the problem of "heat islands" may become severe. They concluded that atmospheric oxygen is practically constant, having stood very close to 20.946 percent since 1910, and that "calculations show that depletion of oxygen by burning all the recoverable fossil fuels in the world would reduce it only to 20.800%." They recommended drastic curtailment of the use of DDT and mercury as well as the control of nutrient discharges, together with early development of technology to reclaim and recycle nutrients in areas of high concentration. (*Man's Impact on the Global Environment: Assessment and Recommendations for Action*, Report of the Study of Critical Environmental Problems sponsored by the Massachusetts Institute of Technology [MIT Press, 1970], pp. 12, 13, 19, 75, 136, 138, 149.)

[6]William Nordhaus and James Tobin, "Is Growth Obsolete?" (paper presented at the National Bureau of Economic Research Colloquium on Economic Growth, San Francisco, December 10, 1970, to be published by the NBER in the proceedings, 1972).

consensus on the urgency of changing the forms and uses of growth is already materializing. As a consequence, the nation already is being confronted with hard choices and the need for painful institutional changes. I submit that both the hard choices and the painful changes required to restore the environment will come much easier in an atmosphere of growth than of stagnation.

Benefits of Growth

Turning to the benefits side of the picture, we are well advised, first of all, to take growth out of the one-dimensional context of the natural environment. In a broader context, the environmental claims against the bounties of growth must include shares not only for cleansing the physical environment of air, water, and land pollution and of urban congestion and sprawl, but also for:

1. Cleansing the social environment of the cancers of poverty, ignorance, malnutrition, and disease.
2. Cleansing the human environment of the degradation and blight of the urban ghetto and the rural slum.
3. Cleansing our personal environment of the fear of crime and violence.

Even with the aid of a rise of 55 percent in GNP and 34 percent in real per capita personal income from 1959 to 1969, we have found in the United States that our inroads on these problems have not kept pace with our rising expectations and aspirations. Imagine the tensions between rich and poor, between black and white, between blue-collar and white-collar workers, between old and young, if we had been forced to finance even the minimal demands of the disadvantaged out of a no-growth national income instead of a one-third increase in that income.

A specific example may be instructive. Between 1959 and 1969 the number of persons below the poverty line fell from 39 million to 24 million, from 22.4 percent to 12.2 percent of a rising population. The improvement came from a 3 percent increase in productivity per year, a drop in unemployment from 6 percent to 4 percent, shifts of the poor from lower to higher income occupations and regions, and an extraordinary growth in government cash transfers, from \$26 billion in 1960 to over \$50 billion in 1970. Every one of these factors was in some way the direct outgrowth of, or was associated with or facilitated by, per capita economic growth.[7] Given their huge stake in growth as a source of the wherewithal and much of the will to improve their lot, the poor could be pardoned for saying, "Damn the externalities, full speed ahead."

[7]Testimony of Robert J. Lampman in *Economic Opportunity Amendments of 1971*, pt. 1, Hearings before the Subcommittee on Employment, Manpower, and Poverty of the Senate Committee on Labor and Public Welfare, 92 Cong. 1 sess. (March 23, 1971).

Looking ahead, the Council of Economic Advisers projected a rise in real GNP (in 1969 dollars) of roughly $325 billion, or 35 percent, from 1970 to 1976. In the face of claims on these increases that are already staked out or clearly in the making–claims that leave only a small net "fiscal dividend" by 1976–it will be hard enough to finance the wars on poverty, discrimination, and pollution even with vigorous economic growth.[8] Consider the problem in a no-growth setting: to wrench resources away from one use to transplant them in another, to wrest incomes from one group for transfer to another, to redeploy federal revenues from current to new channels (even assuming that we could pry loose a substantial part of the $70 billion devoted annually to military expenditures)–and to do all this on a sufficient scale to meet the urgent social problems that face us–might well involve us in unbearable social and political tensions.[9] In this context, one rightly views growth as a necessary condition for social advance, for improving the quality of the *total* environment.

Apart from the tangible bounties that growth can bestow, we should keep in mind some of its intangible dividends. Change, innovation, and risk thrive in an atmosphere of growth. It fosters a social mobility and opens up options that no stationary state can provide. This is not to deny that a no-growth economy, with its large rations of leisure, would appeal to those in the upcoming generation who lay less store by the work ethic and material goods than their forebears. But if they associate this with tranquility–in the face of the intensified struggle for shares of a fixed income on the part of their more numerous and more competitive contemporaries–I believe they are mistaken.

Let me return now to the context of the natural environment, to the growing consensus that we have to stop and reverse the ugly and destructive waste

[8] For the underlying numbers on GNP increases and the claims against them, see the *Economic Report of the President, February 1971*, p. 95. See also chap. 7 of Charles L. Schultze and others, *Setting National Priorities: The 1972 Budget* (Brookings Institution, 1971). Schultze and his colleagues projected a rise in real GNP (1970 dollars) of $353 billion. In current dollars (i.e., allowing for inflation), they foresee a rise from $977 billion in 1970 to $1,585 billion in 1976, a rise of $608 billion. Even with the resulting automatic growth of federal revenues from a full-employment-equivalent level of some $230 billion in fiscal 1972 to $312 billion in fiscal 1976, the "built-in" growth of federal expenditures would leave only a $17 billion net "fiscal dividend" in 1976 to utilize for new programs or expansion of existing programs (pp. 321–33).

[9] For example, in Robert S. Benson and Harold Wolman, eds., *Counterbudget: A Blueprint for Changing National Priorities, 1971–1976* (Praeger, 1971), the National Urban Coalition converted the easy rhetoric of "reordering priorities" into a chart of specific needs. Putting most of its emphasis on "human development programs," the coalition called for a $52 billion rise in federal expenditures on health care in the next five years, $29 billion for income support, $11 billion for education, and $16 billion for aid to state and local governments. Even with its judgment that $24 billion could be cut from military spending over the next five years, this adds up to increased federal spending of nearly $100 billion–apart from the outlays on the battle against pollution!

disposal practices of our modern society. To accomplish this, the taxpaper must foot huge bills to overcome past neglect as well as to finance future collective waste treatment and preserve open space and wilderness. Producers and consumers will have to bear the brunt of outright bans on ecologically dangerous materials and to pay rent for the use of the environment's waste assimilation services that they have been enjoying largely free of charge.

A modest estimate of the demands on the federal budget for an adequate environmental program would raise the present outlay of $5 billion a year to about $15 billion, an increase of some $50 billion over the next five years. Without growth, and given the limits to the congressional will to tax, how could we hope to raise the required revenues?

Or take the case of agricultural and industrial pollution. Imagine the resistance of producers to the internalizing of external costs in a society without expansion and the profit opportunities that go with it. How could consumers be induced to accept the necessary price increases in a world of fixed incomes? Again, if the only alternative, if the ultimate cost, were biological self-destruction, the answers would be different. But in the absence of that fate, or because of its extreme remoteness, growth enters as a vital social lubricant and is the best bet for getting people to give up private "goods" to overcome public "bads."

GNP AND SOCIAL WELFARE

To some of what I just said, the ecologist may reply, "Not so fast, not so fast–when you count all the costs, especially when you subtract the costs of chewing up the environment, you'll find that what you call growth in output and income since World War II is really a case of living off our environmental capital." Or he may say, "The composition of production has changed in such a way that we are no better off than twenty-five years ago." True, he may say these things, but the evidence does not bear him out. But if he adds, "GNP is a mighty sorry index of welfare; you'll have to show me something better than that in rebuttal," the economist says, "Right on!"

Granting that rising GNP is a poor index of human betterment is not to deny that one is generally associated with the other. It should require no lengthy demonstration to show that, while a significant part of GNP is illusory in a welfare sense,[10] wide differences and large advances in per capita GNP are asso-

[10]In the Godkin Lectures, five years ago, I put this point as follows: "If, as *byproducts* in our quest for growth, we destroy the purity of our air and water, generate ugliness and social disorder, displace workers and their skills, gobble up our natural resources, and chew up the amenities in and around our cities, the repair of that damage should have first call on the proceeds of growth. If the damage is essentially a private cost forced on society, as in the case of industrial effluents and smoke discharge, it should be forced back on those private units. But much of the problem and the cost can be met only by government. (If we

ciated with significant differences and advances in well-being. In a careful appraisal of the growth-welfare correlation, Robert Lampman found that a 26 percent gain in real GNP per capita from 1947 to 1962 brought with it a 26 percent gain in per capita private consumption, a distinct improvement in income security, and a significant reduction in poverty. He concluded: "All things considered, the pattern of growth in the United States in the post-war years yielded benefits to individuals far in excess of the costs it required of them. To that extent, our material progress has had humane content.[11]

A question that has more recently intrigued students of GNP is whether it is possible within the framework of a national accounts system to develop a better approximation of welfare. (Noneconomists may be pleased to hear that four observers who have written on this problem in the past four months have come up with four different positions on the subject.)

Economists labor under no illusion that GNP is a satisfactory measure of welfare or that it can be turned into one. They would agree with J. Petit-Senn that "not what we have, but what we enjoy, constitutes our abundance." What makes people think that GNP has become the economist's Holy Grail is the indispensable role it plays in measuring the economy's output potential and its performance in using that potential. It is highly useful and constantly used by economists (1) as a guide to fiscal and monetary policy for management of aggregate demand, and (2) as a measure of the availability of output to meet changing national priorities.

For these purposes, the emphasis of the national accounts must be primarily on market, and secondarily on governmental, demand and output since these are central to national stabilization policies and priority-setting.[12] And for these purposes, the national income and product accounts—with a bit of tinkering here and there—are generally respected and defended by economists.

But when the scene of battle moves to measurement of *social* performance, there is a sharp division of opinion over the possibility and advisability of modifying the GNP—or more properly, the net national product (NNP)—accounts to make them more useful in gauging social performance. Arthur Okun flatly rejected any such thought in his communication to the Office of Business Eco-

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could isolate that part of it which is a direct cost or byproduct of growth . . . we should probably make a subtraction each year from our total output, an adjustment of our GNP figures, to take account of it.)" Walter Heller, *New Dimensions of Political Economy* (Harvard University Press, 1966), p. 111.

[11] Robert J. Lampman, "Recent U.S. Economic Growth and the Gain in Human Welfare," in Walter W. Heller, ed., *Perspectives on Economic Growth* (Random House, 1968), pp. 143–62.

[12] To be precise, net national product is the appropriate measure for gauging the quantity of output available to meet our needs—provided, of course, that the depreciation that represents the differences between GNP and NNP is calculated in a rational and consistent way.

nomics: "I urge that you not try to 'fix it'–to convert GNP into a purported measure of social welfare. . . . Resist at all costs, because . . . nobody can do that job." Edward Denison, writing in a somewhat similar vein, noted that to convert NNP into a welfare measure would require such unattainable measures as an index of real, rather than money, costs incurred in production; a measure of changes in needs that U.S. output must satisfy; measures of the quality of both the human and the physical environment; and a measure of the "goodness" of the size-distribution of income.[13]

Denison also weighed the possibility of getting a better measure of net gains from production by subtracting from the value of greater output the value of the environmental damage caused by producing it. But he concluded (1) that the impossibility of measuring the "goodness" of the environment and the portion of its deterioration traceable to production rules out such an attempt; and (2) that to deduct, as a proxy for that deterioration, outlays made to improve the environment is totally undesirable, since it would mean that the more resources we diverted from other uses to improve the environment, the more we would reduce measured NNP.

But F. Thomas Juster and the Nordhaus-Tobin team take quite a different tack. Juster proposed a comprehensive alternative framework for the national accounts, with emphasis on "extension and refinement of the existing accounts to make them more useful for the analysis of trends in social and economic welfare, while at the same time insuring that a market subsector is retained to facilitate cyclical analysis."[14]

Going beyond the Juster proposals, Nordhaus and Tobin have boldly undertaken to appraise the rough quantitative significance of some of the deficiencies of GNP and, more particularly, of NNP as measures of economic welfare. The flavor of their pioneering probe is suggested by some of the adjustments they make in the NNP numbers (all in 1958 prices):

1. According to their estimates, putting dollar tags on the value of leisure and do-it-yourself work adds a huge \$925 billion to the recorded NNP of

[13]See the comments contributed by Arthur M. Okun to the 50th Anniversary Edition of the Department of Commerce *Survey of Current Business*, January 1972, preprinted in *Brookings Bulletin*, vol. 8, no. 3 (Summer 1971); and Edward F. Denison, "Welfare Measurement and the GNP," *Survey of Current Business*, January 1971.

[14]His ambitious proposals are developed and explained in detail in "On the Measurement of Economic and Social Performance," *51st Annual Report of the National Bureau of Economic Research* (New York: September 1971), pp. 43–52. See also F. Thomas Juster, "A Framework for the Measurement of Economic and Social Performance"; Wassily Leontief, "National Income, Economic Structure, and Environmental Externalities"; and Orris C. Herfindahl and Allen V. Kneese, "Measuring Social and Economic Change" (papers delivered at the National Bureau of Economic Research Conference on Measurement of Economic and Social Performance, Princeton University, November 4–6, 1971, mimeo.).

$560 billion in 1965 (as against an add-on, for example, of $627 billion to the NNP of $292 billion in 1947).

2. They also add in almost $80 billion to represent the stream of services of private and public capital goods (against $37 billion in 1947).
3. Their subtractions from NNP include (a) $95 billion in 1965 (and $32 billion in 1947) representing "regrettables" like police services and national defense, that is, intermediate expenditures that are really costs, not enjoyments, of an advanced industrial society; (b) $91 billion of capital consumption allowances in 1965 (versus $51 billion in 1946) and $101 billion for the capital-widening requirements of growth in 1965 (and a negative $5 billion in 1947); and (c) an allowance of $31 billion in 1965 (as against $11 billion in 1947) for "disamenities" or "negative externalities" representing deterioration of the environment.

Having made these heroic adjustments, they concluded:

> There is no evidence to support the claim that welfare has grown less rapidly than NNP. Rather, NNP seems to underestimate the gain in welfare, chiefly because of its omission of leisure from consumption. Subject to the limitations of the estimates, we conclude that the economic welfare of the average American has been growing at a rate that doubles every 30 years.[15]

All observers agree that no amount of adjustment of the national accounts can capture the myriad values and subtleties that are required to measure social welfare. Indeed, no single index of social welfare can be calculated, because we have nothing like the pricing system to solve the impossible problem of attaching weights to the various components, be they pollution, crime, health, discrimination, or whatever. But to conclude that no *single* index can be constructed is not to undermine or discourage the efforts to develop a set of social indicators, not anchored in the GNP accounts, that will permit us to make better judgments on advances as well as failures in social performance.

DIVERGENT MODES OF THOUGHT

Part of the difficulty in achieving a meeting of the minds between economists and ecologists is that the economist tends to seek optimality by selecting the right procedures—for example, forcing the producer to bear the cost and the consumer to pay the price for waste-disposal access to the environment, thereby creating incentives to abate pollution—rather than prescribing the right outcome, namely, ending or drastically curtailing pollution. He is dedicated to that outcome but prefers to have the market system, rather than a government regulator, do as much of the work for him as possible. Whether a meeting of minds will

[15] Nordhaus and Tobin, "Is Growth Obsolete?"

evolve remains to be seen. Moderates in both camps are moving toward a middle ground, but given existing attitudes, I doubt that full accommodation will be easy.

For his part, the ecologist will have to overcome his natural impatience with concepts of fine balancing of costs and benefits, an impatience that probably grows out of his feelings that cost-benefit analyses lack ethical content and moral inputs and that the more or less infinite benefits of environmental preservation make refined cost calculations more or less irrelevant. And he rightly stresses the nonlinearity of the cost curves of waste disposal as output rises: no-cost or low-cost in the early stages when discharges stay well within the absorptive capacity of the environment, then rising fairly sharply when accumulation and concentration begin to exceed that capacity, and exponentially when they saturate it.

For his part, the economist will have to break out of the web of marginal cost-benefit balance in cases where the relevant costs and benefits can't be captured in that web.[16] Irreparable damage–whether to human health by arsenic and lead poisoning, or to bald eagles by DDT, or to the Alaskan tundra by hot oil, or to the beauty of a canyon by a hydroelectric dam–cannot be handled by the fine tuning of marginalism. Nor is this approach applicable where the benefits are short-run and calculable while costs are long-run and incalculable. So the economist should beware of forcing onto the pricing mechanism jobs that it will almost surely do badly. But he rightly insists that, despite these limitations, the cost-benefit principle is applicable to a very broad range of pollution problems where measurements or reasonable approximations *are* possible.

The question of nonlinearity is a tougher one, in application if not in concept. Few would dispute that there is an initial zone where discharges are not pollutants, because they are well within the regenerative ability of land and water ecosystems that eliminate waste by cycling it through plants and animals and decomposers. Nor is it difficult to agree that, at the opposite end, costs can

[16] The combination of high-intensity feed-grain farming with a high concentration of feedlots for livestock near urban centers may be a case in point. The feed-grain farmer–using chemical fertilizers, pesticides, and herbicides that increase both feed-grain yields and the nutrient runoff that ruins surrounding waters–has been able to bring feed-grain prices down to a level that makes the concentrated feedlots profitable. They, in turn, discharge staggering quantities of animal wastes into urban sewage systems or onto the surrounding land and water. If some way is found of forcing the cost of this discharge back onto these "animal factories," the marginalist's reaction may be to invest in expensive equipment to recycle the wastes back to the land as substitutes for the present chemical fertilizers. But it is quite possible that the high-technology approach that is likely to result from marginal cost-marginal benefit thinking will be the more costly one. The optimal solution may be to decentralize, to go back to the more primitive recycling process of putting the cattle back on grazing land where they can turn forage into waste available as substitutes for chemical fertilizers. (On the other hand, if some agricultural economists are right in their belief that the animal factories are "economic" only because they do not have to absorb the costs of waste disposal, even the marginal approach may do the trick.)

rise exponentially and ecocycles can be destroyed by overloading waters with nutrients, the atmosphere with noxious gases and particulate matter, and so on.

It is in the middle zone that things get sticky. An economist tends to believe that the zone of gradual and roughly linear rise in environmental damage is broad and that it widens—that the cost curve moves to the right—especially when the impetus of full-cost pricing moves science and technology to devise and put in place new techniques of waste disposal and recycling. Where the zone of tolerance or reasonable cost is very limited, as in the case of mercury, marginalism obviously won't do. The total or near-total ban is the only remedy. Whether mercury is a proxy for just a handful of cases or the forerunner of an exponential rise in contamination of the earth, land surface, air mass, and waterways, will determine in good part our relative reliance on total-ban versus marginal-adjustment approaches to environmental action.

The economist is inclined to doubt that such cases will multiply rapidly. Past demonstrations of the capacity of our economy, our technology, and our institutions to adapt and adjust to changing circumstances and shocks are impressive. We are still in the early stages of identifying, quantifying, and reacting to the multiple threats to our environment. It may be that we are too quick in accepting the concept of finite limits and closing physical frontiers implicit in the concept of spaceship earth (dramatized by Kenneth Boulding).[17] At least two previous episodes in U.S. history come to mind to suggest that we may yet escape (or push into the remote future) the ultimate biophysical limits, may yet be able to turn the ecological dials back from the "self-destruct" position without stopping growth in output, energy, technology, and living standards.

The first was the closing of America's geographical frontiers, which allegedly robbed this country of much of its mobility and dynamism. But other frontiers—scientific, technological, economic—soon opened up new vistas and opportunities, new frontiers that far surpassed any physical frontiers.

The second episode is much more recent. We do not need to stretch our memories very far to recall the great furor some twenty or twenty-five years ago about "running out of resources," especially energy, mineral, and other natural resources. We were being told by presidential commissions that we were about to exhaust our supplies of mineral resources and the productive potential of our agricultural land. But as we now know, intensive scientific research and technological development—responding partly to the alarums that were sounded but mostly to the signals sent out by the pricing system—resulted in the upgrading of old resources, the discovery of new ones, the development of substitutes, and the application of more efficient ways of utilizing available resources and adjusting to changes in relative availabilities.

[17]Kenneth Boulding, "The Economics of the Coming Spaceship Earth," in Henry Jarrett, ed., *Environmental Quality in a Growing Economy* (Johns Hopkins Press for Resources for the Future, 1966).

Today, the problem is less one of limited resource availability and more one of growing threats to environmental quality and the metabolism of the biosphere. Concentrations of toxic and nondegradable wastes pose a mounting problem. But at this relatively early stage of our environmental experience and awareness, it seems premature to conclude that mounting problems are insurmountable. As our new knowledge and concern are translated into changes in our institutional arrangements and cost-price structure, strong incentives will be generated to redirect production and technology into less destructive channels.

Letting imagination soar a bit, one can conceive of scientific and technological discoveries enabling us to exploit solar energy, at least for purposes of photosynthesis, and perhaps even to build a proxy for the sun in the form of fusion power sometime in the next half century or so. Such developments might well provide the key to unlock the doors that the ecologist tells us are closing all around us. One gallon of water would give us the energy we now get from seven barrels of crude oil. Electricity would be penny cheap but no longer pound foolish. The recycling of wastes would be routine. The reconstituting of natural resources would come into the realm of the possible. I do not assert that this will happen, only that it may.

Coming back to our own era and moving from the global to the local impact of our environmental debauchery, one can also base some hope on the benign examples of what determination plus the application of fairly modest resources can do in reclaiming resources that once seemed beyond redemption. Striking examples are provided by the reclaiming of San Diego Bay, Lake Washington in Seattle, and the Thames near London (where dolphins again frolic). These examples are hardly decisive, but they offer a significant demonstration, in microcosm, that the process of ecological destruction can be halted and reversed once the volume of pollutants is reduced below the level of natural regeneration or dispersal. One should add that no rounded judgment is possible without taking into account whether pollution was curbed by recycling and changing waste into harmless forms or simply by redirecting the flows and discharging wastes into some other harmful form. The economist who lives by cost-benefit analysis must occasionally die by it.

Implicit in the foregoing discussion is that much of the difference between economists and ecologists on the speed and certainty of our descent into environmental hell rests in their divergent views on the role of technology. The ecologist sees pollution-intensive technology at the core of a mindless pursuit of economic growth. The economist points to the frequency of an inverse relationship between technological advance and pollution, as in materials-conserving and waste-recycling technology. And by institutional changes—such as creating property rights in, and charging for the use of, our collectively owned air, water, and landscape—he believes that technology will become ever more mindful of the environment.

What is important to note here is that the dichotomy runs much deeper than a disagreement on facts. For even if we accept Barry Commoner's verdict that the technology accompanying U.S. growth is the Frankenstein that is destroying our environment, there remains the critical operational question: Is this technology autonomous and out of control, an inevitable concomitant of growth?[18] Or does progress in science and technology respond to social and economic forces? If so, can it be bent to our will?

An affirmative answer to the last two questions is gaining support in recent investigations. The direction of technical changes in the private sector as well as the emphasis of research in the public sector are shown to respond to differences in the relative prices of resource endowments and other factors of production.[19] For decades the pattern of technical change has been biased in the direction of excessive production of residuals by zero-pricing or underpricing the use of the environment into which they are dumped. It follows that assessing the appropriate charges for waste disposal (and putting the right prices on resource amenities) will not only improve the pattern of production to the benefit of the environment but will also stimulate pollution-abating technology. Indeed, as relative prices are changed to reflect real economic and social costs, the longer-run impact on the direction of technological effort may be considerably more important than the short-run resource allocation effects.[20]

As the biases in the cost and pricing system that make pollution profitable are diminished or eliminated, we may well find more technical complementarities than our limited experience leads us to think. Making pollution abatement mandatory by regulation or making continued pollution painfully costly by waste disposal charges will create a sharp spur to pollution-abatement technology. The relevant technology will no longer be treated on a corrective, band-aid, and after-thought basis, an approach that is likely to be inefficient and costly. Instead, it will be done on a preventive, built-in, and advanced-planning basis. Heartening examples of making virtue out of necessity in the form of profitable recycling already abound. And as economic growth leads to the re-

[18]One economist who answers in the affirmative is E. J. Mishan, who says: "As a collective enterprise, science has no more social conscience than the problem-solving computers it employs. Indeed, like some ponderous multi-purpose robot that is powered by its own insatiable curiosity, science lurches onward. . . . " (*Technology and Growth: The Price We Pay* [Praeger, 1970], p. 129).

[19]See, for example, Jacob Schmookler, *Invention and Economic Growth* (Harvard University Press, 1966), a searching study of inventive activity in which Schmookler concluded that the greater part of technical change in the United States has been a response to technical problems or opportunities perceived in economic terms.

[20]I am indebted to my colleague, Vernon W. Ruttan, for this line of thought. He develops and documents his thesis at length in "Technology and the Environment," the Presidential Address delivered before the American Agricultural Economics Association, August 16, 1971, to be published in a forthcoming issue of the *American Journal of Agricultural Economics.*

placement of old processes, equipment, and plants with new ones, it will hasten the change to cleaner and healthier methods of production.

This brings me back to an earlier theme. In the past, the market mechanism (with some assistance from government inducements, incentives, and research and development investments) altered the technical coefficients for traditional natural resources like coal, iron, and oil in response to the signals sent out by the pricing mechanism. Those resources were conserved, while the ones that were largely left out of the pricing mechanism suffered. If prices are put on them now by internalizing the external costs of air, water, quiet, and landscape, it seems reasonable to assume that the market mechanism will cause new shifts in resource use and technology leading us to conserve *these* resources and let Spaceship Earth cruise on a good deal longer.

THE SEARCH FOR SOLUTIONS

Although ecologists and economists are not likely to agree on precisely how far the battle against pollution should be pushed—on how many social and material goods should be given up to overcome environmental "bads"—one perceives some early signs of convergence on the policy approaches and instruments that should be used in that battle. When Barry Commoner traces much of our trouble to the fact that "pollution pays" (or at least that pollution-intensive technology pays) and seven environmental organizations form the Coalition to Tax Pollution, economists and environmentalists are beginning to get on the same policy wave-length.[21]

A greater measure of agreement on the direction of environmental policy action need not and indeed does not imply agreement on ultimate goals, i.e., what level of pollution is tolerable. First, the ecologist is more conscious of, and gives more credence and weight to, pollution's hazards to health, life, and ecosystems. Second, the working environmentalist places a very high value on the aesthetics and amenities of the environment—he is willing to pay a higher price and a higher percentage of his income for a high-quality environment than is the population as a whole.

However strongly the economist may be committed personally to the environmental cause, he tends, first, to put relatively more weight on dangers arising from the social environment. He puts more emphasis on the trade-offs between environmental and social progress, perhaps regarding environmental deterioration as more reversible than social deterioration. Second, as an economist, he feels more bound by society's, than by his own, value judgment as to the desirable level of environmental quality, i.e., the permissible level of pollution.

[21] In July 1971, the Coalition to Tax Pollution was formed by Environmental Action, Inc., The Federation of American Scientists, Friends of the Earth, Metropolitan Washington Coalition for Clean Air, the Sierra Club, The Wilderness Society, and Zero Population Growth. Their first target is the enactment of an effective tax on sulfur oxide emissions.

A third kind of difference in objectives or focus arises out of the conflicting roles of economic growth as both a generator of pollution and a source of weapons to fight it. The ecologist tends to concentrate on the scarcity of physical and natural resources in the earth's skin and its limited supply of fossil fuels, metals, clean air, and water. The economist focuses on the scarcity of total resources, of the total supply of goods and services available in consumable form. Not surprisingly, then, the ecologist sees growth and the technology underlying it mainly as a part of the *problem.* The economist, viewing the huge costs and difficulties of redirecting resources to rescue the environment, regards the bounties of growth as a vital part of the *solution.*

I cannot attempt here anything like a thorough appraisal of the various components of a program to overcome pollution. But neither can I resist making some selected observations on the approaches the nation needs to take. For if we are indeed to make economic growth our environmental servant, not our master, we have to translate general principles and values into operational specifics without delay.

Government Expenditures

There is little disagreement among students of the environmental problem, of whatever discipline, that government has a vital direct role to play in (1) providing public sewage disposal facilities; (2) cleaning up the no-man's land of past pollution whose costs can no longer be internalized; (3) preserving park, forest, and wilderness space; (4) relieving congestion; (5) developing pollution-monitoring devices; and (6) financing research in the techniques of pollution abatement and environmental protection.

Research in specific anti-pollution techniques and, more broadly, in pollution-averting technology is a particularly appropriate object of public sector support. Such research tends to be very costly. Since its benefits are largely external—much of the gain spills over to the benefit of other productive units and to future generations—private units are often unwilling or unable to incur its costs. In the energy field, the development of controlled thermonuclear fusion and of new methods to exploit solar energy fit into this category. Only government has the resources and the perspective to determine whether and how we can harness such energy sources.

In programming its own resource-using expenditures, government should also set an example by plugging in the implicit environmental costs. Military and space efforts, for example, are voracious consumers of energy and materials. This heavy draught on our physical environment should be given full weight in the cost-benefit calculations. We would find, I believe, that redirecting technical efforts and resources away from military and related space enterprises would have a high environmental payoff.

One should also underscore the need for sophisticated monitoring devices, both to measure waste and heat discharges and to measure the damage they do.

Emissions of noxious gases, particulate matter, heat, and other effluents must be measured as a basis for administering either regulations or effluent charges. Yet the *amount* of any given discharge into the air, for example, tells us little about its actual *cost.* Even if we can measure the total load of gas and smog carried by the ambient air in a region, this does not tell us what costs are inflicted on things and people. To the extent possible, then, costs of corrosion of metal surfaces, deteriorated property values, damage to painted surfaces, impairment of health, and so on must be measured.

Even then, we have only begun to measure the costs of pollution and the benefits we will enjoy from curtailing it. What about cleaning and air conditioning bills, smarting eyes, loss of wildlife and recreational space, not to mention the subtle inroads on ecocycles? Even if we could measure these, we can at best only approximate, perhaps by polling techniques, the subjective values attached to clean water and air and quiet surroundings.

Balanced against the benefits must be an appraisal of the costs of installing anti-pollution machinery and processes or altering production techniques to overcome pollution. On these, we are getting more quantitative data and experience every day as we intensify anti-pollution efforts. In devising specific programs to restore the environment, we must be keenly aware of (1) the need for improved cost and benefit information, and (2) the importance of designing programs that take realistic account of our limited knowledge of actual costs and benefits.

Regulations and Charges

As already mentioned, direct regulation and prohibition are instruments for environmental protection that must be used where intolerable dangers to health and life are involved or where irreversible and infinite damage to the environment is threatened. Also, a combination of regulations and user charges[22] may be the best way to go about certain pollution control problems, especially during a transitional period. For example, an absolute limit on emissions might be established by regulation to prevent really dangerous abuses of air or water at the same time that a uniform tax per unit of discharge is imposed as the main anti-pollution instrument. By and large, however, economists strongly prefer taxes and user charges to direct regulation on at least four grounds.

First, the regulatory power is often slow and cumbersome. By the time regulations are designed and applied, and then enforced through prolonged and costly court proceedings, much of the battle is lost.

Second, under the unrelenting pressure of producing units to internalize benefits and externalize costs, regulators bend more readily than tax collectors.

[22] Robert M. Solow has been particularly instructive on the subject of regulations and subsidies versus taxes in "The Economists' Approach to Pollution," his vice-presidential

Since the large and powerful can exercise far greater pressure than the small and weak, the impersonal and objective approach implicit in a tax per unit of discharge provides a fairer competitive environment. And for both large and small producers, it is a far healthier incentive atmosphere when energies are devoted, not to out-maneuvering the regulators, but to reducing pollution taxes by reducing pollution.

Third, fees or taxes accomplish any desired level of pollution abatement more cheaply than regulation. Reduce sulfur oxide pollution by a ban on emissions in excess of a certain amount, and all emitters have to conform to the regulation, even though the cost per unit of reduction will be far higher for some producers than for others. But put a tax on the emissions—a proportional or progressive penalty on discharges of sulfur oxide—and the factories that use processes conducive to low-cost cutbacks of pollution will reduce emissions more than those for whom it is a high-cost undertaking. Any prescribed quality of ambient air can be achieved at a lower cost through the proportional charge approach than through an arbitrary limit. And the incentive to depollute does not stop at some arbitrary cutoff point—the more pollution is cut, the lower the tax.

Fourth, by decentralizing some of the decision making and leaving discretion in the hands of the individual polluter to decide how far to go and what methods to use in minimizing his payments to the government, the tax or charge approach does not require as much centralized information. Also, the process of collecting the tax or charge will itself yield additional information—and the level of the tax or charge can be fairly readily adjusted in the light of the new information. In a field beset by large factual gaps and uncertainties, this economizing of information is no small advantage.

The tax or charge is also far superior to the subsidy approach, which has two damning flaws. First, in its usual form—fast tax write-offs or direct subsidies for installation of pollution control equipment—it is a very costly way to stop pollution. In effect, it prescribes a particular way of doing the job, i.e., through waste treatment facilities, when there might be considerably cheaper ways of doing it, e.g., modifying production techniques, substituting less toxic for more toxic materials, recycling wastes, relocating production, and so on. Moreover, since the alternative is free use of the air and water for waste disposal, the subsidy may have to cover the full cost of abatement before the producer will accept it. The second flaw is found in the very nature of the subsidy. The subsidy does not internalize the costs, but simply shifts them from one segment of the public—the users of foul air and water—to another segment, the general taxpayer.

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address to Section K of the American Association for the Advancement of Science, at the annual meeting in Chicago, December 1970. An adaptation of the address was published in *Science*, August 6, 1971.

What kind of a system of taxes or user charges would be most effective? Fortunately, this question is engaging the energies and ingenuity of many economists today. Effluent charges, taxes, auctioning of pollution rights, materials-use fees—these are a few of the entries. The effluent fee, charge, or tax would simply charge so-and-so-much per unit of pollutant. The Coalition to Tax Pollution, for example, would tax sulfur emissions at 20 cents a pound by 1975, arriving at this level via four annual 5-cent steps.[23]

Another approach is to determine the permissible level of air or water pollution, issue certificates to pollute in this amount, and auction them off to the highest bidders. Competitive bidding for the certificates would raise the cost of pollution so high as to create a strong incentive to depollute.[24]

An intriguing proposal to impose a comprehensive materials-use fee has recently been made by Edwin Mills. He would charge a materials-use fee to the original producer or importer of specified materials removed from the environment. The level of the fee would be set high enough to cover the social cost of the most harmful way in which the material would normally be discharged into the environment. To the degree that the actual waste disposal was less harmful than the maximum, the fee would be refunded. Mills's proposal, though hardly operational in its present form, has the advantage of focusing on the total problem of materials disposal and making a comprehensive correction for the divergence between social costs and private costs.[25]

As a guide to thinking, the Mills proposal is particularly helpful because it underscores the fact that not just the level of output but the form of our technology and the nature of our disposal processes are important in determining the environmental impact of economic growth. True, as Allen Kneese notes, the physical law of the conservation of mass means that we don't really consume things in any ultimate sense. We simply change them from usables to residuals.[26] But even a growing mass of residuals can leave less and less pollution in its wake if we succeed in changing the form, the degree of recycling, the location, and the durability of those residuals in a constructive way. Under present institutional arrangements, the price system is rigged against constructive

[23]In its release on the subject (Washington, D.C., July 22, 1971) the Coalition said: "We believe that pollution taxes are a much-needed tactic to combat pollution. It will be necessary to make the economic self-interest of polluters consistent with the goal of a clean environment if we are to achieve this objective. Pollution taxes, unique among pollution control strategies, accomplish this."

[24]See J. H. Dales, *Pollution, Property, and Prices* (University of Toronto Press, 1968); and the discussion in *Economic Report of the President, February 1971*, pp. 114–22.

[25]Edwin S. Mills, "User Fees and the Quality of the Environment," an essay to be published in a volume honoring Richard A. Musgrave, which will be edited by Warren Smith, Department of Economics, University of Michigan.

[26]Allen V. Kneese, "Environmental Pollution: Economics and Policy," in American Economic Association, *Papers and Proceedings* (May 1971).

disposal. Once we redress the balance, it will be financially advantageous to minimize the burden of residuals on the environment.[27]

Before leaving the subject of charges and taxes, I should record several caveats and reminders. Even after we have devised workable techniques of internalizing the external costs of pollution, we still have to resolve a very difficult problem of choice. It is one in which the obvious and reasonably measurable costs of overcoming pollution are set against benefits that are in large part intangible and unmeasurable. The social cost of upgrading the quality of air or water is, if not yet known, at least knowable. The social benefit of an additional unit of water or air quality is in large part in the realm of values and hence unknowable. That does not, however, make the choice in any sense unique. Like many other social choices, it has to be made through the political process. Science can develop solutions and inform the political process, but it cannot dictate the answers.

Further, in setting up any system of charges, we should not overlook the potential for large-scale economies through collective methods of industrial waste disposal and recycling. We already do it in the treatment of municipal sewage. Perhaps there are opportunities for gathering liquid effluents, and possibly even smoke emissions, into central depollution and recycling facilities that would cost materially less per unit of output than handling them on a plant-by-plant basis. (The use of a Rhine tributary in this way is one case in point.) If it is kept in mind that the objective is to get the full costs of environmental use into the prices that consumers pay—and at the same time to cut those costs—rather than to force costs on individual producers, the net cost of pollution control may be reduced substantially.

The potential of other forms of institutional change should also be explored. For example, in seeking to minimize the intrusion on the environment associated with the production of energy, we should look not just at cleaner sources but at more efficient uses. Electricity is one of the most rapidly increasing uses of energy, yet we dump about two-thirds of the heat into the environment, using only one-third in constructive application. If we can develop complementarities through the joint production of steam and electricity for space heating and water heating and air conditioning, we could reduce both the energy costs and the related capital costs. The problem is institutional. The way the relevant industries are regulated and the products are priced, joint production is not

[27]For illuminating discussions of the role of the pricing system and means of putting it to work in preserving the environment, see the papers by Solow, Ruttan, and Mills already cited, as well as the article by Larry E. Ruff, "The Economic Common Sense of Pollution," *The Public Interest*, Spring 1970, pp. 69–85; R. U. Ayres and A. V. Kneese, "Production, Consumption and Externalities," *American Economic Review*, June 1969, pp. 282–97; and Hendrik S. Houthakker, "The Economy and the Environment" (remarks before the Cleveland Business Economists Club, April 19, 1971, available as a mimeographed release by the Council of Economic Advisers, Washington, D.C.).

interesting. Moreover, we have the wrong urban design for the purpose. As it happens, what we need for efficient heat and energy use is also optimal for transportation and communication. Whether we would tolerate the drastic changes in zoning ordinances and the degree of central planning that would be required to achieve the potential complementarities and economies is very doubtful. But we should not ignore the possibilities.[28]

It should also be recognized that anything short of a comprehensive system of materials-use fees will require taxes not just on discharges from productive processes but also on the purchases of products whose use inflicts injury on the environment. The case of herbicides and pesticides is most directly in point. Levying taxes on the sale of these products will bring their use more in line with total social costs. And it will produce revenue to help government cleanse the water of eutrophying residuals.

Removing Existing Governmental Subsidies to Pollution

Finally, as we work to terminate the subsidies that are implicit in our failure to charge for fouling the environment with liquid, solid, gaseous, and thermal wastes, we should also work to end the huge explicit subsidies in existing government programs that have the same effects, namely, to overstimulate high-pollution processes and technology, overproduce many products, and over-exploit natural resources. Agricultural subsidy programs that idle good land, with consequent chemical "overkill" to force more output from the remaining land, are one obvious example. Some aspects of transport regulation fall under a similar shadow.

But the most flagrant example is provided by our tax system. To continue stimulating the overexploitation of oil, coal, timber, and every mineral from iron to vermiculite and spodumene by big tax subsidies in the form of excessive depletion allowances, capital gains shelters, and special deductions becomes ever more anomalous. Here is another case where the believers in the market-pricing system ought to live by it. The public is subsidizing these industries at least twice—once by rich tax bounties and once by cost-free or below-cost discharge of waste and heat.

Far from stimulating conservation and rational use of fossil fuels, both the form and the price impact of the tax preferences work the wrong way. In the case of oil, neither the percentage depletion allowances nor the deductions for intangible drilling and development costs offer any incentive to more efficient and thorough exploitation of oil in the ground, no premium for fuller recovery of the potential oil in the well. And since much of the subsidy is reflected in higher prices of oil lands and lower prices of oil products, economic incentives for full use of the available technology to achieve higher recovery ratios are once

[28] My colleague, Ralph Hofmeister, provided the foregoing example.

again reduced. Adding to the diseconomies are refinery discharges of effluents into the air and water, tanker flushings and spillages, offshore oil well fires and spills, all of which inflict costs on the general public and do not now find their way into the costs of production. The net result is to underprice and overproduce petroleum products and the energy derived from them. (It should be noted that oil import quotas work, uneconomically, in the opposite direction, as do the tight oil allowables set by state regulatory commissions.)

Coal is another case in point. Its capital gains and percentage depletion preferences, while less flagrant than in the case of oil and gas, cut the price of mining coal below its social costs and hence speed up the rate of exploitation. The entire polluting sequence–from the strip mining that scores the land to the smoke and heat emissions involved in production–is magnified. With coal coming into generating plants at too low a cost, public utility commissions set the price of electricity below actual cost (private and social combined). Too much electricity is produced and sold. As a result, physical capital and other productive resources are pulled away from their optimal uses in other, less pollution-intensive industries. The net effect of tax subsidies interacting with failure to charge for the use of air and water is both a less efficient use of the nation's resources and greater pressure on the environment.[29]

In the environmental context, the temptation is to make the tax preferences conditional on proof of nondespoiling extraction and nonpolluting utilization of coal. But this would load onto the tax system and Internal Revenue Service agents a burden of policing environmental crimes that they should not have to bear. In this case, the simplest solution (conceptually, though not politically) is also the most effective: end the specific tax subsidies as well as the general spillover cost subsidies that mining and drilling now enjoy.

Distributional Effects

As we increasingly inject the costs of waste disposal into the prices of our products, GNP may not suffer greatly in quantity, but it will change in quality, containing more environmental safeguards and amenities and less material output. Given the high income-elasticity of demand for environmental services, the intuitive reaction of most readers of this paper will be inwardly to smile with satisfaction.

But how will the poor and the black ghetto dweller view the matter? What do environmental attractions, aesthetics, and amenities mean to them? Perhaps they mean somewhat cleaner air and water, but more pertinently they mean

[29]In the context of the earlier discussion of GNP impacts, one might note the resulting effect on the national accounts. Owing to resource transfers, the net effect on measured GNP has probably been limited. But NNP is overstated because the social costs of waste disposal and disamenities are not counted and subtracted, nor is the cost treated as a depreciation of our environmental capital.

higher prices of the goods that will now bear the costs of producing those three A's and little help with what Congressman Charles Rangel from Harlem says "ecology" means to his constituents: "Who's gonna collect the damned garbage!"

So before we at this forum take much solace in the improved mix of the national output as *we* see it, we had better be sure (1) that the ghetto dweller is cut in on the environmental dividends as *he* sees them, and (2) that as the prices of goods and services are raised because industry's free ride on public air and water and land is ended, the nation simultaneously compensates the poor through more effective measures to redistribute income and opportunity.

CONCLUSION

In the complex and often baffling field of environmental control, no one—surely not the economist—has all the answers. But good economics is the handmaiden, not the enemy, of the good environment. What the economist believes he can contribute is a better understanding of how economic growth, cost-benefit analysis, and the market-pricing system can be made to work for us rather than against us in the battle to protect our natural environment and improve the quality of existence.

Those who defend economic growth rest their case essentially on the following points:

1. For all the misallocations and mistakes, environmental and otherwise, that have been made in the process of growth, it is still demonstrably true that growth in per capita GNP has been associated with rising levels of human well-being.
2. Much if not most of the environmental damage associated with growth is a function of the *way* we grow—of the nature of our technology and the forms of production. By prohibiting ecologically deadly or dangerous activities and forcing producers to absorb the cost of using air, water, and land areas for waste disposal, growth, technology, and production can be redirected into environmentally more tolerable channels.
3. To provide social and financial lubrication for this painful process as well as to repair the ravages of past neglect of the environment requires the resources, revenues, and rising incomes that growth can put at our disposal.
4. Side by side with the problem of restoring our physical environment is the even greater problem of overcoming the ills of our human and social environment. Those ills seem to be cumulating even faster and to be even more stubbornly resistant to reversal than our environmental ills. How

> we could hope to cope with them and avoid unbearable sociopolitical tensions within the context of a stationary state is not apparent.

Coupled with a conviction that economic growth can more than atone for its sins is a belief that its environmental vices can be diminished and its virtues magnified by greater use of the pricing system, by putting appropriate price tags on use of the public environment for private gain. The economist readily recognizes that environmental quality is a highly subjective good on which it will be difficult to put those price tags. He also readily acknowledges that where damage to health, life, or the biosphere—either now or in the future—are severe or even infinite, the pricing system has neither the speed nor the capacity to deal with the problem.

But even recognizing such limits, the economist rightly asserts that across a large part of the pollution spectrum the pricing system *is* applicable. By charging producers—and ultimately consumers—for the full cost of waste disposal, their self-interest will be put to work in slowing or even reversing the march toward a degraded or exhausted environment.

To make economic growth not only compatible with, but a servant of, a high-quality environment won't be easy. Even after ecologists identify the source of the trouble, engineers identify solutions and develop monitoring devices, and economists identify appropriate taxing and pricing schemes, there remain crucial tests of public will and political skill. To get producers and consumers to pay the full cost of using the environment for waste disposal and to get the public to accept the reordered priorities and pay the higher taxes that will be needed to redirect growth and clean up past environmental mistakes will require great acts of both will and skill.

[From the Saturday Review of the Society, Oct. 21, 1972]

THE DOOMSDAY SYNDROME

The environmentalists, a leading British scientist charges, may be the most insidious of all plunderers of our planet. Using "a technique of calculated overdramatization," they have deflected attention from the genuine ecological issues we face and blinded us to solutions that exist now.

(By John Maddox)

Prophets of doom have multiplied remarkably in the past few years. It used to be commonplace for men to parade on city streets with sandwich boards proclaiming, "The End of the World Is at Hand!" They have been replaced by a throng of sober people—scientists, philosophers, and politicians—proclaiming that there are more subtle calamities just around the corner. The human race, they say, is in danger of suffocating itself by overbreeding, of poisoning itself with pollution, of undermining its essential character by tampering with heredity, and of weakening the basic structure of society through too much prosperity.

The questions that these latter-day doomsayers have raised are complex and interesting; the spirit in which they are asked is usually too jaundiced for intellectual comfort. Too often, reality is oversimplified or even ignored, so that there is a danger that much of this gloomy foreboding about the immediate future will accomplish the opposite of its intention. Instead of alerting people to important problems, the "doomsday syndrome" may be as much a hazard to human survival as any of the environmental conundrums society has created for itself.

Nobody doubts the sincerity of the contemporary prophets of calamity, and nobody would disagree that modern society is confronted with important tasks that must be tackled with a sense of urgency. In advanced societies machinery must be devised for the more equitable treatment of the poor and the disadvantaged. Urban life, although better than it used to be, surely leaves much room for improvement. Even where medical care is excellent, ways of preventing untimely death and unnecessary disease remain to be discovered. And in less-developed societies there are the more basic tasks of providing people with adequate food, housing, and schooling. These are difficult problems, but they are capable of solution in the foreseeable future if enough time and money are spent on them. By contrast, the questions the doomsayers generally raise are rhetorical ones, either because they are based on incorrect premises or because they are unanswerable with the knowledge we possess at the present moment. The risk is that too much preoccupation with the threat of distant calamity will lead to a kind of quietism by diverting our attention from good works that might be accomplished now.

The doomsday cause would be more telling if it were more securely grounded in facts, as well as better informed by a sense of history and an awareness of economics. The major defect in the argument that calamity is just around the corner is its imprecision. Some doomsayers fear that the burning of fuel in the scale to which modern industry is accustomed will wreck the earth's climate, but few meteorologists are able unambiguously to endorse such prophecies. Others fear that the use of pesticides will irrevocably damage the human race, but that is an overdramatic statement of the need to carefully regulate the way in which such chemicals are sprayed on crops. Still others fear that modern biology, with its artifically fertilized eggs and its detailed understanding of genetic processes, will create a race of robots, but such a concern flies in the face of the past five centuries of medical history, for the most part a consistent record of humane endeavor. In short, the weakness of the doomsday prophecies is that they are exaggerations. Many of them are frighteningly irresponsible.

The flavor of these prophecies of disaster is well illustrated by the work of Dr. Paul Ehrlich, whose book *The Population Bomb* startled a good many people when it was published 4 years ago. "The battle to feed all of humanity is over," Ehrlich wrote. "In famines, hundreds of millions of people are going to starve to death in spite of any crash program embarked on now." Ehrlich went on to describe in a somber way the rate at which the population of the world is increasing, the inconveniences that are likely to result therefrom, and some ways of striking a better balance between the population growth and available resources, especially in developing parts of the world.

Nobody will deny that it is important to control, if not the size of a population, then its rate of growth. In advanced societies population control is increasingly becoming an accepted function of good government. In developing countries it is generally recognized as a prerequisite to economic progress. Ehrlich's warning of imminent famines on a massive scale is unrealistic. The truth is that the total production of food on the earth is now increasing much faster than the population. For most of the sixties, the population of the world grew at about 2 percent a year, while agricultural production in the same period increased by 2.7 percent annually. And in the past few years there has been especially encouraging progress in the hard-pressed countries of Southeast Asia and India, where food production has increased nearly twice as fast as population, due largely to the introduction of new strains of wheat and rice. Nor is there any reason to believe that the "green revolution" will slow down in the coming years. Population control is therefore desirable, not as a means of avoiding calamity, but because it can accelerate the steady improvement of the human condition.

Famine is only one of several hypothetical catastrophes that are said to flow from population growth. Ehrlich and other doomsayers argue that high population density produces individual disorientation and increased social tension. One common argument for supposing that crowding as such is bad for people starts from experiments that have been carried out with laboratory animals, principally rats. The best-known experiments, performed by Dr. John B. Calhoun, showed rats kept in unusually crowded conditions developed all kinds of psychological disturbances—mother rats took to infanticide, males became unnaturally aggressive, and the mortality rate rose. So is it not reasonable to suppose that people living in metropolitan areas will be more disturbed than those who live in rural areas? With growing population densities, will not violence within and between countries become that much more prevalent? These are common suspicions. Dr. Ehrlish and his wife, Anne, in their book *Population, Resources, Environment*, write that there are "very high correlations among rates of population growth * * * and involvement in wars."

The trouble is that the analogy between rats and people is at best tenuous—gregariousness of the kind that led to the development of cities thousands of years ago distinguishes the human race from rodents. And the belief that violence and war accompany crowding rests on the most shaky statistical basis. Who, after all, would claim that the Netherlands, the most crowded of all Western European countries, is more given to violence than, say, the United States?

Implicit in these dire warnings of the consequences of population growth is a misleading method of prediction that gives more credit to simple arithmetic than it deserves. If the population of the world is at present doubling every 35 years, does it necessarily follow that the population will multiply by a fourfold factor in the next 70 years, so as to reach 14 000 million by the year 2040? In *The Population Bomb* Ehrlich is scornful of those whom he calls "professional optimists * * * who like to greet every sign of dropping birth rate with wild pronouncements about the end of the population explosion." And even in the more soberly written *Population, Resources, Environment*, he chooses to base predictions of the future population of the earth on the most pessimistic calculations appearing in studies funded by the United Nations, which assume that there will be no change in the fertility of women of childbearing age between now and the end of the century. In reality, however, there are already signs that fertility is declining in developing countries in exactly the same way as, but possibly more rapidly than, it declined in Western Europe between 50 and 100 years ago. One of the strangest features of Ehrlich's description of the population explosion is the bland assumption that the social forces that have brought about stability in the developed countries—the improvement of the quality of education and medical care, for example—are inapplicable elsewhere. Is it any wonder that the predominantly Western preoccupation with the population explosion seems like patronizing neocolonialism to people elsewhere?

In much the same way that environmentalists worry about the effects of population growth on our physical and psychological well-being, so, too, they decry its effect on natural resources. In the United States, at least, this is an honorable tradition going back to the end of the 19th century, when Gifford Pinchot, head of the U.S. Forest Service, wrung his hands over the prospect that timber in this country would be used up in roughly 30 years, that anthracite coal would last for only 50 years, and that other raw materials such as iron ore and natural gas were being rapidly depleted. Seventy years later the same complaints are heard. The environmentalists have coined the phrase "our

plundered planet" to express their anxiety about the probability that petroleum will be much less plentiful a century from now and that the time will soon come when high-grade copper ores are worked out. The fallacy in this reasoning is that society has never been uniquely dependent on the balance of raw materials in common use at a particular time. If copper becomes scarce or merely expensive, more aluminum will have to be used in its place. If natural diamonds are expensive, then we will make them synthetically. In any case, although supplies of such raw materials are known to be limited, the point at which they seem likely to be exhausted tends to recede with the passage of time so as to be always just over the horizon. Indeed, despite what the environmentalists say, the present time appears to be one in which forecasts of scarcity are less valid than ever. Petroleum may be much harder to obtain a century from now, but in the past few years scientists have laid the foundations for wresting energy from hydrogen and minerals such as uranium in large quantities, so that future decades will be much better off than anybody could have expected even a decade ago. And, however strange it may seem, the real economic cost of extracting such metals as lead and copper from the ground is still decreasing as exploration and the techniques of mining and metallurgy become more efficient. In terms of their availability at least, the earth's resources are becoming more and more plentiful.

Ecological catastrophe is also high on the list of public fears for the future. As another leading doomsdayer, Dr. Barry Commoner, puts it in *The Closing Circle*, "* * * in our unwitting march toward ecological suicide, we have run out of options." What he and the other environmentalists who echo his opinions wish to imply is that the relation between people and the environment is so delicate, and the dependence of the human race on its surroundings so complete, that many of the effects of our activity on the natural world may destroy the capacity of the earth to support life.

One recipe for ecological disaster, for example, holds that pollution of the surface layers of the oceans by insecticides or chemicals may destroy the microscopic plants that turn the energy of sunlight into chemical form, help to support marine life of all kinds, and replenish the oxygen in the atmosphere. Another theorizes that the accumulation of carbon dioxide produced by the burning of fossil fuels may so increase the temperature on the surface of the earth as to transform the present pattern of weather and perhaps even melt the Antartic ice. Fortunately, these chains of events are by no means inescapable. For one thing, the processes that are supposed to lead to disaster are only imperfectly understood. Moreover, their scale is still puny in relation to the size of the earth's envelope—the ecosphere, as it is called.

Tiny though the earth may appear from the moon, it is in reality an enormous object. The earth's atmosphere alone weighs more than 5,000 million million tons, more than a million tons of air for each human being now alive. The water on the surface of the earth weighs more than 300 times as much—in other words, each living person's share of the water would just about fill a cube half a mile square. So while it is not entirely out of the question that human intervention could at some stage bring about changes in the ecosphere, for the time being the vast scale on which the earth is built should be a great comfort to us all.

But even if the human race is unable to harm the ecosphere significantly, is there not a danger that it may destroy itself more directly? In the past few years the nature of biological research has been repeatedly held up as a potential threat to man's survival. Genetic engineering is a somber phrase, no doubt, conjuring up visions of long rows of test-tube babies bred to governmental specifications. But the concept is less frightening when one recalls that horse breeders and plant growers have been practicing it for centuries. And why should communities that have rejected the eugenic devices already available—forced choice of marriage partners, for example, or selective infanticide—throw their principles to the winds now that molecular biology has come along?

Even the quite real prospect of artificially fertilizing human eggs does not contain the seeds of unwelcome social upheaval that many people suppose. The truth is that the most obvious uses of these new techniques are therapeutic, not subversive. To be sure, biological research has raised novel ethical problems. How, for example, does a doctor decide which of several equally needy patients should have access to an artificial kidney machine or receive a kidney that becomes available for transplant? But the fact that these problems are novel is neither an argument against the new techniques nor a justification for the belief that biological research is full of unmanageable social dangers. What

justification can there be for the supposition that the same medical men who have developed antibiotics for the treatment of infectious disease and vaccines for its prevention will seize on the new developments to pursue malevolent objectives?

But what of the possibility that science and technology may undermine the integrity of society in much more subtle ways? This is an old fear, of course, which in its crudest form amounts to unregenerate obscurantism. In the past few years the theme has appeared again in a revised and updated form. In his book *Reason Awake*, Dr. René Dubos writes: "Man has always lived in a precarious state, worried about his place in the order of things. In the past he was threatened chiefly by natural forces that he could not control, and he experienced fear because of ignorance of the cosmos and of his own nature. Now threats and fears derive in large measure from science and its technologies, paradoxically the most characteristic products of human reason." And elsewhere he adds, "Most would agree that science and technology are responsible for some of our worst nightmares and have made our societies so complex as to be almost unmanageable."

The flaw in these protestations is that they label technology, and the science from which it springs, as a subversive force in society. It is true, of course, that technical innovations frequently have unexpected consequences. This has always been the case. Who would have guessed 50 years ago that the motor car would create the suburbs of North America? The fact that ocean beaches are so much more crowded now than half a century ago is also a consequence of the tremendous expansion of the automobile industry. But is it sensible to wish that internal combustion engines had not been invented for the sake of avoiding overcrowding at the beaches? Is it not preferable to enjoy the other benefits of the invention and to regulate the crowding of beaches by other means? And in any case, where such developments are in question, is it not entirely misleading to suggest that the automobile industry has grown to its present size for reasons connected with the character of technology and not because a need for its product became apparent? On issues like this, the doomsday literature is dishonest.

The introduction of the wheel into primitive societies must similarly have been attended by unforeseen developments. Then, as now, the immediate benefits of innovation may be predictable, but the more distant consequences, beneficial or harmful, are harder to foresee. The moral, of course, is that governments have a responsibility to insure that most of the social consequences of technological progress are positive ones. To pretend with Dr. Dubos that such discrimination is impossible and that all technology is therefore suspect is to suggest that society is powerless to regulate its own affairs. The argument that technology is an all-powerful juggernaut pressing the humanity out of society usually cloaks a pessimistic belief in the impotence of social institutions. The challenge is not to keep science and technology at bay but to control them and, in particular, to make sure that they do not become dehumanizing influences on our lives.

One of the most common misconceptions about technology is that it consists entirely of gigantic, tax-supported programs for sending rockets to the moon. In reality, most technologists work toward much less spectacular objectives—building safer and cheaper bridges, for example, or devising ways of drying coffee without loss of flavor. Those who complain about technology and its effects would be on stronger ground if they concerned themselves with devising ways for society to exploit science and technology. The key question is, who says which innovations are worth while? Some decisions have to be made by individuals in their role as consumers. Others are left to manufacturers. Still others, which have a political flavor in the most general sense, must be taken by governments acting on behalf of the communities they represent. Governments have all too often been unwilling to shoulder their responsibilities. They have, for example, accepted the introduction of jet planes without taking into proper consideration the extra noise such aircraft cause. They have encouraged industrial development without thinking sufficiently about the unavoidable side effects of industry, pollution being chief among them. They have encouraged urbanization without paying enough attention to city planning.

Were these the complaints of the environmentalists, their cause would be entirely laudable. But by slipping into the pretense that science and technology have between them established such a powerful hold on society's development that the survival of the human race may be undermined, they have sidestepped the real issue, which is to guide, not eliminate, technological progress. There is no reason to think that technology will be less valuable in the future than it

has been in the past in liberating men and women from drudgery and so improving the quality of their lives. Paradoxically, the environmental message, at least in its crudest form, is self-defeating.

The main reason the message is so often presented so crudely goes back to the origins of the modern environmental movement. The first environmentalists were probably the scientists who, toward the end of World War II, sensed that the development of nuclear weapons posed a grave threat to the human race. In 1945 Dr. J. Robert Oppenheimer, the scientific director of the Los Alamos program that produced the first atomic bomb, made the point with characteristic eloquence: "In some crude sense which no vulgarity, no overstatement can quite extinguish, the physicists have known sin, and this is a knowledge which they cannot lose."

Throughout the fifties, the campaign to ban the testing of nuclear weapons picked up momentum. In the early years of the decade, the first test explosions of hydrogen bombs carried the scientists' initial sense of alarm to a far wider spectrum of the population. In 1954, when four Japanese fishermen were killed by radioactive dust from a thermonuclear explosion, the entire world was given a vivid demonstration of the potential destructiveness of nuclear energy. By the late fifties, nuclear weapons tests had become commonplace, and the amount of radioactive fallout was reaching intolerable levels. The discovery of strontium 90 in the skeletons of young children was a powerful assault on the public conscience. With military strategy still dominated by plans for thermonuclear retaliation, it was no wonder that the decade ended with the sense that doomsday was just around the corner.

At about the same time, ironically, the concern of the early environmentalists with the perils of nuclear explosions to human health began to win wide acceptance, and in 1963 the major powers signed a treaty prohibiting above-ground testing of nuclear weapons. Suddenly, the environmentalists constituted an army that had tasted blood but seemingly had no further battles to fight. The year before, Rachel Carson had published her now-famous study of the misuses of pesticides, *Silent Spring*, thereby launching an entirely new phase of the environmental movement. The problem was that many environmentalists continued to use the same apocalyptic rhetoric they had employed so effectively to express their indignation over the unregulated dissemination of nuclear weaponry—a truly apocalyptic danger—to decribe a much more subtle and complex phenomenon.

Miss Carson herself was concerned almost entirely with the way in which insecticides were being used in the United States. Many of her complaints were well founded—it is absurd that insecticides should have been employed to clear insects from inland lakes with such abandon as to kill the fish as well as the insects. Another of her many cautionary tales described how the use of an insecticides similar to DDT against the Japanese beetle in the cornfields of the Middle West made life easier for a still more dangerous pest, the corn borer, which normally was preyed upon by the Japanese beetle. In this and other ways she marshaled enough evidence to demonstrate that pesticides should be more carefully regulated. The most seriously misleading part of her narrative involves the relating of horror stories about the misuse of DDT to create the impression that there are no safe uses for pesticides at all.

Rachel Carson thus set the tone of much subsequent environmental literature by employing a technique of calculated overdramatization. The silent spring itself was an apocryphal season in "a town in the heart of America" created by Miss Carson's fertile imagination. Her book begins with what she calls "a fable for tomorrow." Once—"all life seemed to live in harmony with its surroundings. * * * But then a strange blight crept over the area and everything began to change. Some evil spell had settled on the community: mysterious maladies swept the flocks of chickens; the cattle and sheep sickened and died. Everywhere was a shadow of death. The farmers spoke of much illness among their families. In the town the doctors had become more puzzled by new kinds of sickness appearing among their patients. There had been several sudden and unexplained deaths, not only among adults but even among children, who would be stricken suddenly while at play and die within a few hours."

The calamity, of course, was caused by the use of pesticides. Miss Carson goes on innocently to reveal that "this town does not actually exist, but it might easily have a thousand counterparts in America or elsewhere in the world." By playing this literary trick on her readers, she provided not merely graphic illustration of the fact that excessive amounts of pesticide could kill animals as well as insects but also a sense that excessive use was almost unavoidable.

Paul Ehrlich's *The Population Bomb* is a splendid illustration of how the technique of calculated exaggeration has flourished. After a tautly written account of how "the battle to feed all of humanity" has been lost, sufficiently vivid to have most readers on the edges of their seats, Ehrlich concludes with the smug apology that he, like any scientist, "lives constantly with the possibility that he may be wrong." However, no harm will be done if his argument proves false, Ehrlich continues, for "if I am wrong, people will still be better fed, better housed and happier . . ." The difficulty, of course, is that alarm does not provide the best atmosphere for finding rational solutions to those problems that are truly worrisome. Aesop knew what happened to shepherd boys who cried wolf too often.

Barry Commoner also uses Miss Carson's technique. In his book *Science and Survival*, for example, he writes that "as large a body of water as Lake Erie has already been overwhelmed by pollutants and has in effect died." The truth is now what it was when the book appeared in 1963, namely, that Lake Erie had indeed been seriously afflicted by pollution, for such a shallow body of water could not be expected to remain unchanged under the assault of the vast amount of sewage and industrial effluent that surrounding cities discharged into it. But throughout the 1960's the lake somehow managed to support a thriving fishing industry. In 1970 it yielded 25,000 tons of fish. Nobody can know for certain why the trout have been replaced by other species of fish—is it in fact the sewage or perhaps the influence of the Welland Canal, which, bypassing Niagara, connects Lake Erie to Lake Ontario? By now it seems to have been generally agreed that something must be done to limit the discharge of effluents into Lake Erie, but the proclamation that the lake is already "dead," whatever such a phrase may mean, has probably given Lake Erie more prominence than it deserves. To be fair, in his more recent book, *The Closing Circle*, Commoner does not say the lake is dead but merely that "we have grossly, irreversibly changed the biological character of the lake and have greatly reduced, now and for the foreseeable future, its value to man." But even this more moderate statement of his position is doubious if the assertion of the irreversibility of the damage is taken at face value.

Implicit in the pessimistic outlook of many ecologists is a common stand on the nature of living things and their relationship with the big environment. In *Science and Survival* Commoner has a chapter entitled "Greater Than the Sum of Its Parts," which attempts to demonstrate that the properties of living things cannot be explained solely in terms of the properties of the molecules that make them up.

"There is, I believe, a crisis in biology today. The root of the crisis is the conflict between the two approaches to the theory of life. One approach seeks for the unique capabilities of living things in separable chemical reactions; the other holds that this uniqueness is a property of the whole cell and arises out of the complex interactions of the separable events of cellular chemistry. Neither view has, as yet, been supported by decisive experimental proof. The molecular approach has not succeeded in showing by experiment that the subtly integrated complexity and beautiful precision of the cell's chemistry can be created by adding together its separate components. Nor has the opposite approach, as yet, discovered an integrating mechanism in the living cell which achieves the essential coordination of its numerous separate reactions."

In its essence this argument echoes the old 19th-century belief in what was then called "life force"—a special quality of living things—whose credibility has steadily diminished ever since the first laboratory synthesis a century and a half ago of substances usually considered by-products of life. The modern equivalent of this neovitalism holds that the "web of life"—as Darwin termed the way in which different species are linked together by their mutual dependence—is so complicated that it cannot be submitted to the methods of mathematical analysis. This is one of Commoner's arguments. In the trivial sense, of course, the point is incontrovertible—who would seriously set out to calculate the weight of a full-grown locust when it would be much simpler, and probably safer as well, simply to put it on a scale? But this does not imply that the weight of a locust is in principle incalculable, that there are features of the ecosphere that lie beyond the scope of conventional science. Among the environmentalists there is a temptation to emphasize the unity of the living world in circumstances when it would be more appropriate to consider different parts of it separately. After all, the special character of science is its ability to understand complicated problems by breaking them into their constituent parts.

What happens when scientists attempt to examine the world in its entirety is beautifully illustrated by the controversial Club of Rome study published last spring, entitled *The Limits to Growth*. The study, carried out at MIT under the leadership of Dr. Dennis L. Meadows, is based on a computer simulation of the world and purports to show that many of the more gloomy prophecies of the environmentalists can be upheld by mathematical calculations. The computer is programed with information about the population of the world (for this purpose broken down into three numbers representing the population of children between zero and 15, the population of adults of reproductive age, and the population of those whose reproductive life is over), as well as a number indicating the amount of money invested in industrial capital, another indicating the amount of arable land, one that is supposed to stand for the stock of unrenewable resources, and one that is meant to be a measure of pollution. The object of the exercise is to calculate how these and several other interrelated variables will change in the course of time. In my opinion the results fully justify Gunnar Myrdal's description of the study as "pretentious nonsense."

To cite one example, the stock of nonrenewable resources such as minerals will obviously decrease over time at a rate determined in part by the size of the world's population and by the quantity of material consumed each year by a single individual, which is in turn dependent on the amount of industrial output per person and ultimately on the investment in new factories of various kinds. Dr. Meadows and his colleagues calculate that if there is "no major change in the physical, economic, or social relationships that have historically governed the development of the world system," there will come a point in the next century when the diminishing stock of natural resources brings about a decrease in industrial growth, a consequent decrease in the amount of food available per person, and then, in due course, a return to the bad old days of the 18th and 19th centuries, when the death rate rose rapidly because of starvation and even an increasing birth rate was unable to prevent a population decline.

The first thing to be said about such a prediction is that even the best possible computer model is no better than the assumptions about the real world with which it is programed. And even very large computer models, such as Dr. Meadow's, are never large enough to take into account all the possible relationships between one thing and another. So it is no wonder that the Club of Rome study has been forced to make drastic simplifications that even the extremists in the environmental movement usually manage to avoid.

The most serious error in the study involves something economists call aggregation—the combining of things that ought not to be considered as one. For example, the authors have been compelled by the limitations of their equipment to represent the totality of pollution on the earth by a single number, based on world industrial production. Having lumped pollution and industrial production together, the authors cannot take into consideration the obvious fact that modern technology can control the first without affecting the second at all.

These simplifications, apparently built into the Club of Rome's computer model, make nonsense of the study. To add another example, *The Limits to Growth* represents the world's stock of nonrenewable resources with a single number. In one particular calculation it was assumed that the amounts of nonrenewable resources in the earth's crust in 1970 were the equivalent of 250 years' supply at the then rate of consumption. On the face of things this was a generous assumption, for the known reserves of a great many common materials such as lead and mercury are unlikely to last nearly so long. But the history of the past few decades has shown clearly enough that relatively scarce materials are constantly being replaced by more common ones—copper, for instance, has been superseded by aluminum in many branches of the electronics industry. Moreover, by representing the present stock of raw materials with a single number, the study has overlooked a cardinal law of economics, which holds that increasing scarcity and, consequently, higher prices would stimulate exploration for new materials and also make it more practical to mine ores of lower quality.

In general, economics is not the strong suit of the environmentalists. And, unfortunately for their case, most of the issues they tend to present as questions of life or death for the human race are essentially questions of economics. Consider urban air pollution. The overriding issue is not whether cleaner air can be provided (we know it can) but how much taxpayers, and in particular the owners of cars and factories, are prepared to pay for that amenity. Exactly the same is true of the noise produced by jets, the overcrowding of

beaches, and even the extent to which farmers are allowed to use pesticides. On such issues there is a need for a better understanding of the economics of the communal good.

Because the relationship between communities and their surroundings is often determined by economic considerations, it is not surprising that different communities should have different objectives and that each should strike its own balance between exploitation and conservation. This is another way of saying that only prosperous communities will pay much attention to environmental amenities. One of the more serious dangers of the extremist wing of the environmental movement is that by insisting on the catastrophic implications of present tendencies, it may alienate the countries of the developing world, not yet rich enough to aspire to the kind of pollution-free future on which the more prosperous nations have set their sights. This was plain enough at the United Nations Conference on the Human Environment held in Stockholm last June, where it proved to be extremely difficult to hammer out a common platform, partly because of the inevitable conflict of interest between rich and poor nations.

The extremists have created the false impression that prosperity itself is the enemy. After all, cars are so numerous on the roads of a wealthy nation because its citizens are able to pay for them. And the heaps of aluminum cans that deface a countryside indicate that consumers can afford the added expense of disposable items. But insisting on the relationship between prosperity and pollution obscures the incontrovertible truth that the level of prosperity now common in developed nations has also purchased better health services, educational systems, and a host of other social benefits to which less fortunate nations still aspire. To people in the developing world environmental concerns are simply not of the highest priority.

The political consequences of this tactlessness by people from industrialized societies are serious. The intellectual sins committed by the environmentalists are more serious still. The common justification of their technique of deliberate exaggeration is the claim that it is necessary to stir people up, to get things done. But people are easily anesthetized by overstatement, and there is a danger that the environmental movement will fall flat on its face when it is most needed, simply because it has pitched its tale too strongly.

Avoiding a Limit to Growth

(By W. Donham Crawford, President, Edison Electric Institute)

Not long ago, at a special press conference in Washington, a group of government officials, economists and scientists gathered to review the results of a study sponsored by the "Club of Rome" and published under the title of *The Limits To Growth*. The Club of Rome is an organization set up about 4 years ago by an idealistic Italian industrialist with an interest in ecology. The study on the limits of growth is the first commissioned by the club, and consists of a computer model developed at the Massachusetts Institute of Technology. It forecasts doom for mankind if we try to continue on the path of industrial and technological development on which we are now moving. The study represents the latest, and probably the most thoroughgoing, expression of a point of view which has been gaining increasing attention in this country over the past months.

During the next few minutes I would like to talk with you about the concept of growth, particularly as it relates to our Nation's long-range goals, and the place of energy in achieving those goals.

I do not want to characterize the MIT study unfairly. The authors have taken on an enormous, complex task. They attempt to treat the entire Earth as a single system and, in order to approach this almost impossible problem at all, they were forced to make a number of assumptions and aggregations of data which are difficult to defend in themselves. For instance, they assume that the population growth rate of the world is the same all over the Earth, although growth rates can vary from country to country and region to region by a factor of six or more. They lump all kinds of pollutants together, as well, ignoring differences in the toxicity and nuisance levels. One can understand and accept these assumptions, and make appropriate mental adjustments in regard to the conclusions. The central point of the study is that if things continue on their course, man will come to disaster in about 50–100 years. Stretch the 50 years to 500 years

and the point remains the same. At some time in the future, if things go on as they are, man will come to an end.

This is one of the basic flaws in the study—the assumption that things will go on as they are. Ever since economic growth really began some 200 years ago, with the inception of the industrial revolution, any philosopher, economist or scientist wanting to delve into the future would have been constrained to forecast worldwide doom if he began by plotting existing expotential growth against established technology. A well-known British economic journal has pointed out that in 1872 any scientist could have told you that a city the size of a modern London or New York was impossible because there would be no room to stable all the horses required for intra-city transportation—and the danger of asphyxiation from manure would be extreme.

Discussion of economic growth outside the strict limitations and technical language developed by economists is fraught with danger for the amateur. However, the Club of Rome challenges us, as citizens of modern society, to address this difficult concept and to try to reach our own conclusions. In doing so, we must avoid, for example, confusing gross national product with growth, as so many people seem to be doing. GNP is one measure of economic activity which has proved helpful to our understanding in recent years. The non-expert accepts it in the same way he accepts the Dow-Jones average as a measure of the stock market. Of course, any investor will tell you that the market measure most meaningful to him is the price of the shares he owns. The Dow-Jones, the Consumer Price Index and gross national product are all useful to us in measuring economic activity, but they are little more than that.

The traditional view of economics held by most of us in this country suggests that economic growth should provide the greatest good for the greatest number of people. We have said that in working toward this goal we should allow individuals the freedom to select the goods they want. The essence of freedom is the ability to select one's own goals and to have the opportunity to achieve them. In these terms, economic growth means the increasing ability of a society to provide people with opportunity to choose and attain the goals they elect for themselves.

Energy has been one of our most important tools in working toward our goals. Used in machines, it has multiplied man's ability to get work done. The increasing availability of energy has made possible the development of technologies which have created jobs, produced income, and brought higher living standards.

The germ of truth in the Club of Rome study is that in achieving the economic goals we have set for ourselves we may, if we are not careful, shut off some important and desirable options. The conclusions of the study are so pessimistic they may appeal to the gloomy side that dwells in most of us. What is not obvious to the casual reader is that the pessimistic conclusions stem directly from the pessimistic assumption that technological development has come to an end, and that there are no roads out of the slough before us.

A technological optimist rejects this assumption, and therefore the conclusion, almost out of hand. I would range myself on this side. It seems to me the real problem before us is to find ways to continue to use energy effectively to avoid limits on our options, particularly in the environmental area, the importance of which we have come to appreciate more fully in recent years.

The technological pessimist says the solution to our problems lies in using less energy. The optmist takes the reverse position. He see, for example, that sewage treatment plants, which we need by the thousands, will require large amounts of energy to pump millions of gallons of waste through screening, filtering and clarifying systems. He sees the necessity for recycling used materials and knows the energy required is enormous—90 million kilowatt-hours a year for one automobile recycling plant, for instance. He sees the need for creating new jobs in order to raise living standards for all the people, and this means increasing energy supplies. Remember, about two-thirds of the electric energy consumed in this country is utilized by commerce and industry. Only one-third is used in the home.

The question he asks is, How can we use energy most effectively and in what form can it be used best? Increasingly, the answer is: to use electricity.

A recently completed study shows that, in 1980, if all residential space heating in the United States were electric rather than largely fossil-fueled, as at present, the environmental impact would be substantially less and a smaller quantity of economically useful natural resources would be consumed. A similar study comparing electric road vehicles and conventional cars, both assumed to meet relevant federal aid quality standards, leads to a similar conclusion in favor

of the electric vehicle. These studies, made by an independent consulting organization, are available on request. We will be glad to send you copies. The point they underline is that energy is needed to carry out the environmental improvements we desire and that electricity is the most environmentally desirable form of energy to be used in many instances.

Electricity is not the problem. It is a major part of the solution to the environmental problem.

Those who would limit the use of electricity sometimes suggest that the most direct way to do so would be to charge large users the same or a higher rate per kilowatt-hour than small users. Let me take a moment to point out the fallacy in this idea.

In all businesses the total cost of goods or services is made up of fixed and variable costs. Fixed costs are those that the producer incurs regardless of the quantity he produces. The more his output, the more units of production there are over which to distribute the fixed cost. Variable costs, on the other hand, are directly related to the quantity produced. The variable cost of the millionth unit is essentially the same as the variable cost of the first. Depending on the proportions of these two types of costs, the average total cost will decline with increasing production.

Most manufacturers have considerable control over their ratio of fixed to variable costs. They can start up or shut down production when it is most prudent and they can accept orders for delayed delivery. They are also free to commit or not commit themselves to plant expansion. Electric utilities must produce kilowatt-hours whenever their customers demand electricity. Service must be instantaneous. There can be no stockpiling of the product. Moreover, utilities are obliged to expand if the requiremets of their customers increase. They do not have the option of refusing business. As a result, power companies have much less control over the ratio of their fixed to variable costs.

If an electric company customer uses only small amounts of electricity, the price he pays will mainly reflect his share of the fixed costs involved in serving him—the expense of building powerplants, transmission lines, costs of metering and billing and so forth. If he uses large amounts, these fixed costs are distributed over more kilowatt-hours and the cost per kilowatt-hour will be less. Variable costs, being a function of the number of kilowatt-hours actually consumed, will of course, be the same per kilowatt-hour for all customers. However, about 75 percent of the total cost of producing and delivering electricity represents fixed costs.

This explains why a large user usually has a lower unit cost than a small user. No subsidy of any kind is implied. The difference in the average cost per kilowatt-hour is due solely to the spreading of fixed costs over a larger number of kilowatt-hours in the case of the larger user.

If the same rate or higher rate were charged with increasing consumption, the price would not bear a valid relationship to the cost of service and would obviously not be a true cost. Such penalty rates are clearly discriminatory by nature.

This is not to say that higher prices should not be charged if the cost of providing the service is higher, as is true during peak load periods. Many utility companies use this approach, by charging higher prices for onpeak service than for offpeak service.

There are those who suggest inverting electric rate schedules for other reasons, among them as a means for redistributing income. Such an approach would require divorcing prices from costs, and this concept makes most economists uncomfortable. Artificially conceived rate structures designed to achieve social objectives are of dubious value, in my view. It would seem wiser to attempt to attain the desired ends through more direct means.

Increasing costs of providing electricity, including costs of capital, environmental costs, and other expenses, lead to the inescapable conclusion that the long-range downward trend in the average price per kilowatt-hour has changed direction, at least temporarily. At the same time, competitive forms of energy are still feeling the same cost pressures and the relative positions are not changing in any marked way. For this reason, it seems unlikely that the pattern of the electric growth—about two and a half times the average annual growth rate of total energy use in this country—will change in the near future.

Our nation was blessed with substantial resources of raw energy—coal, gas, oil, falling water, and nuclear fuels. Most of our economic hydroelectric sites have been developed and gas is now in short supply. Largely for economic reasons, we have increasingly turned to foreign sources for oil. While our reliance on

imports will doubtless continue for the foreseeable future, particularly with respect to low-sulfur fuel oil, it seems a questionable policy from the point of view of national security over the long term. Significant oil resources in Alaska and Canada are as yet untapped, but it apparently will be years before fuel from these sources can be brought to market. Oil shale offers another important, though less accessible natural resource for fuel supply. Nuclear power has come along rapidly, but at the moment represents only a small fraction of our total requirements.

This leaves coal as our fuel resource in greatest abundance and with the most usefulness in many areas for the short term. Here the difficulty lies in stringent environmental restrictions. I believe there is an urgent need to modify policies and regulations, at least on a temporary basis, so as to permit the continued and increased use of our coal resources in areas where viable alternatives are not available.

Electricity generation today does not place an insuperable demand on the Nation's fuel reserves—our estimate indicate that in 1970, power generation consumed approximately 0.1 percent of the Nation's proven resources of coal, oil, and gas. The problem is not so much the extent of consumption of our fuel resources as it is an inability to use these resources in an environmentally and economically acceptable way. For the more distant future, technology can provide us with additional energy sources, such as the breeder reactor, fusion, and possibly solar energy.

Today, fuel and energy developments in this country are affected by a melange of governmental policies and regulations which are often in direct conflict with each other. My own view is that we might be well served by a new institutional mechanism for coordinating these policies in a way that will meet the public interest. A model for the kind of instrumentality I have in mind, at least at the Federal level, is the National Security Council which constitutes a forum for Federal policies in the national security field. The Department of State, the Defense Department, and other affected governmental agencies participate. The Domestic Council functions in a similar manner for domestic issues.

A National Energy Council, reporting directly to the President and consisting of the heads of various Federal agencies with energy responsibilities, could be most helpful in bringing order to many disconnected, inconsistent, and incoherent policies under which we now function. Such a Council would concern itself with coordination of governmental policies relating to the interface between energy supply, fuel supply, and environmental considerations. Primary reliance for meeting the Nation's energy needs would continue to be placed on the fuel and energy industries. This is the system that has served our country so well in the past and will do so in the future.

The structure of the Council would require a careful definition, for energy activities at the Federal level now include research and development, licensing and regulation, as well as policymaking. The setting up of an energy "czar" should certainly be avoided. The strength of this country's economic and political system is that we have multiple-decision centers, each one balanced by others, so that the best overall conclusion will result. Conceivably, the President might appoint distinguished members of the public to the Council as a means of providing a broader point of view to its deliberations.

Government agencies which come to mind for representation on the Council are the Interior Department, the Atomic Energy Commission (with respect to its developmental activities), the Office of Science and Technology, the Office of Emergency Planning, the National Bureau of Standards, the Council on Environmental Quality, the Council of Economic Advisers, and possibly the Department of State. The Chairman of the President's Council of Economic Advisers might serve as Chairman of the Energy Council, as Dr. McCracken did with respect to what I understand to be a temporary committee on energy policy. Appropriate roles would need to be defined for regulatory bodies, such as the Federal Power Commission, the Atomic Energy Commission, and the Environmental Protection Agency, for environmental and consumer interests, and for the fuels and energy industries themselves. Perhaps such roles would be in the nature of advisory committees.

The Council would not supplant a Department of Natural Resources if such a body comes into being as recommended by the President. Instead, the Council's functions would complement the activities of the new Department.

Some examples of subjects for consideration by the Council might be the following:

1. A conclusion is reached by EPA that the technology does not yet exist to remove sulfur from stack gases on a demonstrable, practicable basis. The Council would discuss alternative approaches to meeting national air quality standards over the next few years, such as facilitating the importation of low-sulfur fuel oil, encouraging exploration for natural gas, and giving credit for the use of tall stacks to mitigate ground level SO_2 concentrations. Conclusions of the Council would be conveyed to appropriate Government agencies for implementation.
2. Court decisions, such as those pertaining to Quad Cities and the 1899 Refuse Act, place in jeopardy the electric utility industry's ability to operate new plants needed to meet peak loads expected in the near future. The Council would provide an established instrument for promptly arriving at recommendations to remedy the situation.
3. FPC concludes that foreseeable sources of additional gas supply will not meet the Nation's needs in the years ahead. The Council finds that accelerated research into coal gasification is required and communicates this conclusion to appropriate Government agencies and to industry research organizations, such as the newly established Electric Power Research Institute, for implementation.

These suggestions are only my own thoughts on the subject and I am sure that they can be substantially improved upon. They do represent one approach which seems to me to have some merit.

Whatever the means may be, we need to address ourselves as a nation to assuring that we continue to have an ample supply of energy to meet the growing demands for environmental cleanup, for more income for more people, and for a better quality of life for all Americans.

The Ecological Effects of Growth

(Testimony of Dr. George N. Woodwell, Brookhaven National Laboratory)

Many of the ramifications of growth have been explored recently in documents familiar to you such as *The Limits to Growth* (Meadows et al. 1972). *Blueprint for Survival* (Goldsmith et al., 1972) and Mishan's *The Cost of Economic Growth* (Mishan, 1967). These documents establish that many facets of growth as we have known it through the past century will slow or stop within the next decades. The principal question is whether we will have any control over the transition, avoiding the discomforts of Malthusian limits or analogous chaos. I applaud your attempt to address the question directly.

I shall examine an aspect of the cost of growth that has not been explored adequately in these documents or elsewhere. This is the dependence of man on the Earth's living resources. I believe that the data I shall summarize indicate that this dependence is far greater than the world's intellectual, political or economic leaders have commonly acknowledged, that irreversible changes are occurring at the moment that have great importance for all, and that, while significant steps have been taken recently in our own air and water pollution bills, much more powerful steps are needed to prevent major, irreversible changes in the capacity of the Earth for support of man.

First, the problem is urgent, perhaps the very most urgent of the plethora of urgencies of our time. There is a common tendency to think of pressures on environment as directly correlated with the growth of population; and so they are. The population of the Earth is expected to double in the next 30–35 years. But pressures on environment are also a product of human activities. People who have cheap energy, for instance, can command more of the Earth's resources than those who do not. Indeed, one of the advantages of having an abundance of energy is precisely this control over other resources. The aggregate demand on resources is the product of the number of people times their average impact per person. Various indices suggest that aggregate impact is increasing very much more rapidly than the population alone. A review of the "Gross Domestic Product," which does not include services, taken from the U.N. Statistical Yearbook (1968), shows an annual increase since 1950 of 5 to 6% or a doubling time of 12–14 years (SCEP, p. 119). The Gross Domestic Product might be taken as one index of the aggregate effect of man on environment.

Similarly, the amount of energy used in support of the technological segment of society is another index of aggregate demand on resources. World use of fossil fuel energy has increased for the last century at about 4 percent per year, giving a doubling time of about 18 years (Hubbert 1968).

Such considerations suggest that the aggregate effects of man on environment are doubling in between one and two decades, perhaps less. This is a very short time when we consider the time required for major changes in social systems.

Certain effects increase at much greater rates. In the 15 years between 1951–66 a 34 percent increase in food production was accompanied by a 146 percent increase in use of nitrates and a 300 percent increase in use of pesticides. These relationships are shown in table 1. There appears to be every reason to believe that the further intensification of agriculture will require similarly disproportionate efforts, perhaps more so, as less fertile lands are put into production. There is reason, moreover, to fear that toxification of the environment over large areas will aggravate this problem significantly. It is difficult to exaggerate the speed with which these problems are developing or their potential for disruption.

Second, contrary to the arguments of many economists and others, the earth's biota is our single, most important resource. While protecting it will not assure wealth and grace for man, its decimation will assure increasing hardship for all. We can gain insight by examining certain aspects of the earth's energy budget, including especially the nonbiotic energy used directly by man in support of technology and the energy used by plants in support of the essential qualities of that thin surface layer of the earth that contains all life. I use energy for my simplification because energy is the basis of the wealth of the western nations and, as we have seen, it can be used as an index of total human activity. I use it also because those who advocate reliance on growth as a solution for all problems rely on an abundance of cheap energy which can be used to substitute resources for one another as need arises. Energy can also be used to measure the intenstiy of biotic activity on a regional or global basis. A brief discussion and comparison of these two flows of energy, that through man-dominated systems and that through the earth's biota, provides an indication of the scale of human activities and offers one index of the limits of the earth for support of man.

First, world consumption of nonbiotic energy is summarized for 1967 in Table 2. Total energy use worldwide, including all nonbiotic sources, was estimated as about 45×10^{12} KWH. Virtually all of it was from fossil fuels. About 35 percent of the total energy was used by the United States and about 86 percent by the "developed" countries. If all the people of the world used energy at the U.S. rate in 1967, total energy use would have been 6.6 times higher than it was then. Chauncey Starr, writing in *Scientific American* in 1971, estimated that if the people of the underdeveloped countries were able to reach the present U.S. standard of living by the year 2000, total world energy consumption would be 100 times the present consumption. This is, of course, impossible. Petroleum is the most versatile form of readily available energy at present. M. K. Hubbert in 1969 provided an authoritative appraisal of world supplies, reproduced here as Fig. 1. By either of the two assumptions as to the total quantity of petroleum on earth, we can expect to enter the declining phase of extraction and use worldwide by the year 2000 or sooner. A 6-fold increase in rate of use is not possible; the maximum use may be 2 times the present rate, but will decline almost immediately because of declining supplies. Coal is a very much larger resource and might sustain greatly increased use, but at substantial cost to environment in strip mining and in air pollution. Nuclear energy's potential is not being realized for a variety of important reasons. Other nonbiotic sources of energy are small. The possibilities for sustaining a doubling time of 15–20 years for energy use worldwide for more than another doubling look questionable at present simply on the basis of the size of the resources and the magnitude of the problems of extraction and distribution. Supplies of nonbiotic energy are finite. The problems of supply in the next decades are sufficient of themselves to give pause to those who assume that growth as we have known it in recent decades can continue to float on cheap nonbiotic energy.

The second flux of energy I wish to examine is the flux through biotic systems, which is summarized in Table 3. This flux, while often overlooked by those considering the issues of the human future, is far more fundamental to human welfare than the nonbiotic energy we have been considering. With only trivial exceptions this energy represents all of the life of the earth including man and sets one limit on the size of human activities. Hidden in the table is all of human food, both plant and animal, some of man's fuel, his fiber and other resources; hidden also are services such as the stabilization of water flows, the amelioration of climate, the cleaning of water and air, and the control

of plant and animal populations. These services are performed at no cost to man by systems that would build and repair themselves. The services to man can be disrupted and lost; when they are, large costs accrue to society for flood control, for land stabilization, for subsidies of various types, for pest control, and for various forms of social repair and relief. It is reasonable to assert that when large increments in the earth's capacity or maintaining that this flux of biotic energy are lost, the earth has lost a significant segment of its capacity for support of man. This energy, too, is finite: the total for the world was estimated most recently by Whittaker and Likens (1973) as 841 x 10^{12} KWH of net primary production per year. Net primary production is the dry organic matter or energy that is left over after the needs of the plants for metabolism have been filled of the plants for metabolism have been filled; it is the energy available to support man, other animals and the decay organisms. More than 60 percent of the earth's net production is terrestrial, most of that in forests. Cultivated land provides for only 43 x 10^{12} KWH of this total. Probably somewhere between 5 and 10 percent of the world total is used directly now in support of man as food, fuel or fiber. The fraction of the net production of the sea used as food may be higher than that for land because we harvest only fish and may be harvesting fish now at close to the maximum rate that the oceans can sustain.

The most difficult question for us is how much of this flux is used indirectly in support of man through maintenance of essential service? How big can human activities get with respect to the rest of life before all aspects of life in the broadest context of the meaning of "life" are progressively degraded? It seems very doubtful that we will be able to substitute energy-based technologies for all of the functions of forests, for the functions of the biota of the oceans, or for the biota of the coastal wetlands. These are simple systems in the limited sense that they run themselves. They do not require man-controlled energy to sustain them; they do their job in support of man without any tinkering from us. How can we measure the total function of these systems in support of man? Keeping in mind the age-old principle of ecology that no single-factor analysis is ever adequate, we may use as one criterion a comparison of the flux of energy through natural systems with that through man-dominated systems to establish an estimate of the equivalence between the constructive forces of ecological succession and the biotically destructive forces of fossil-fueled man. Table 4 offiers such a comparison (Woodwell 1972).

Less than 0.1 percent of the solar energy impingent on the top of the atmosphere is fixed in photosynthesis and made available as net production. This does not mean that photosynthesis is inefficient, it simply means that the rest of the solar energy is used in other ways. Photosynthesis provides an average worldwide density of net production of 1.4 kWh/m^2/year of the surface of the earth. The non-biotic energy flux controlled by man when averaged over all of the land, is very much lower, about 0.3 kWh/m^2/year; the average flux in the United States is about 1.67 kWh/m^2/year, appreciably less than 5–15 kWh/m^2 characteristic of forests and agriculture in the temperate zone. In areas such as Manhattan and Brooklyn the flux of nonbiotic energy probably rises to 1,000–3,000 kWh/m^2/year (Table 4), nearly as high as the mean solar flux at the top of the atmosphere. These areas are clearly dependent on other regions for food, fiber and essential services. The significance of the worldwide fluxes and the U.S. flux require further analysis. What can we say about the effects on the biosphere of the growth of human activities to the point of using an average of 1.67 kWh of energy annually per square meter over the entire United States? The answer is sufficiently complex to be easily ignored. I shall offer an answer in two segments. First, a general segment showing the pattern of change in the biota caused by disturbance; second an examination of certain specific effects that are more or less directly caused by energy production.

There is a popular assumption that the earth's biota is a more or less random array of species, capable of adjusting by evolution or short-term successional rearrangements to virtually any disturbance. The assumption is misleading. A hundred years of post-Darwinian experience has shown that there are clear, quantitative relationships between species by whatever criterion we choose for measurement. If we choose energy, we can show that there is in any mature natural community a transfer of 10–20 percent of the energy fixed by the plants to animals that eat plants. Consumers of these animals commonly take 10–20 percent of this energy. And so on through two or three levels of carnivores. No matter how large the plant population and its net production, carnivores

will be rare because there is simply not enough energy transferred to them to support them in abundance. This does not mean that they are unimportant; they exert controls over the sizes of populations below them in the trophic structure that keep the flow of energy within the 10–20 percent limits. This simplification emphasizes that there are quantitative relationships between populations in nature. Natural systems have powerful interactive mechanisms to maintain these relationships and to preserve the integrity of biotic structure. There is overwhelming evidence that man is now overriding these interactive mechanisms by changing the basic chemistry, physics and therefore the biology of the earth, locally, regionally, and worldwide. What are the changes, how important are they, and what should be done?

The changes, no matter how complex they may appear and potentially advantageous in one or more respects, are reductions in biotic structure that can only be considered unstabilizing and retrogressive. The pattern is consistent throughout all of the plant and animal communities of the earth. First, the highly specialized carnivores, perched high in the food web, are reduced or eliminated either by the accumulation of toxins such as the chlorinated hydrocarbons or by changes in the food web below them that leave them without an essential ingredient of their environment. Second, the entire array of plants and animals is changed from one in which large bodied, long-lived species occur to one in which small-bodied, short-lived, rapidly reproducing plant or detritus-eating organisms predominate. We see this pattern now in the reduction of forests in the Los Angeles Basin by toxins in the air. The forest is replaced by low growing shrubs and annual herbs. It can be illustrated dramatically in agriculture where use of broadly toxic compounds as insecticides has eliminated predators and competitors not only of the target species but also of other previously benign inhabitants of the crop, releasing insect and mite populations as new "pests," all of which are herbivorous competitors with man for the crop. It can be seen in carefully designed experiments such as those at Brookhaven National Laboratory where ionizing radiation has been used to reduce the structure of a forest systematically to offer an opportunity to study such questions. It can be seen in the biotic impoverishment of the lands around the Mediterranean and in eutrophic and polluted streams, lakes, and estuaries.

Data from Lake Pontchartrain obtained by R. Darnell (1961) illustrate these points for a disturbed estuarine lake. The lake was receiving significant quantities of organic matter at the time of the study and was turbid with Mississippi River silt. It contained a surprising diversity of consumers, most of which showed a dependence on two or more sources of food (fig. 2). Most, but not all, were dependent on organic detritus in some degree. It is clear that with further disturbance such as elimination of bottom-dwelling animals by siltation, by dredging, or by an oil spill, the fish populations would shift still more heavily toward plant and detritus-eating forms low in the list insofar as the fish survived at all.

It is important that here few species of fish were dependent directly on the plants; most fed only indirectly through detritus, zooplankton, or other fish. Disruption of one of these populations has implications throughout the system, although the changes are often difficult to measure. The pattern, however, is clear: a reduction of complexity favoring fewer forms that are detritus-feeders. We guess that this would mean a reduction in total production of fish; it would certainly mean a reduction in the variety of fish and in the opportunity for harvest of food that would otherwise be totally unavailable to man, who does not eat phytoplankton, most small zooplankton or detritus.

These are gross disturbances: minor disturbances such as small changes in the chemistry of environment must be assumed to bring increments of change in the same direction, although individual increments may be unmeasured and unmeasurable. We are learning now that fish and various other animals communicate by chemical signals at incredibly low concentrations. With the experience of DDT and radioactivity behind us we would be naive to assume that small concentrations of other substances cannot be accumulated, do not have significant effects at low concentrations, and cannot be returned to man in toxic quantities. Indeed, we must assume that they do have biotic effects and manage our affairs to assure that in those systems, such as the oceans, lakes, streams, and terrestrial communities, where biotic integrity is important to us, there is no accumulation of minor chemical insults that can become significant in total. This conclusion bears directly on the recent legislation on air and water pollution as we shall see in a moment.

There are abundant signs that growth in human influences has already progressed to the point where these individually small insults are worldwide. Clear worldwide effects seem to be limited to an increase in the CO_2 content of air, the worldwide distribution of DDT residues and PCB's to the point where virtually every organism contains detectable residues, to fallout radioactivity, to dust in the atmosphere, and to a worldwide reduction in biotic diversity through a combination of direct exploitation and changes in habitat. While each of these has potentially great significance for man, I use them only to emphasize that we are changing the physics, chemistry, and biology of the earth worldwide, a clear sign that growth in the aggregate effect of man has already exceeded the point where we can rely longer on the classical assumptions of an Adam Smith-based economics, in which free enterprise organizes itself through the self-interest of the entrepreneur and the economy grows unbridled into a limitless world.

The magnitude and seriousness of the ecological problems associated with the current scale of human activities is shown most lucidly by a consideration of the acidity of rainfall in the Northeastern United States. Normally rain has acidity that is determined by the CO_2 in the atmosphere. On the pH scale rain usually has a value of 5.6–6.0, indicating slight acidity. Increasing acidity is indicated by lower numbers, each whole unit representing a tenfold increase. During the past decade rainfall in widely separate parts of the Northeastern United States and in Scandinavia has been commonly in the range of 3.8–5.0, occasionally as low as 3.0 (Likens et al. 1972). The high acidity has been correlated with an increase in the amount of sulfate and nitrate in the rain and is thought to be caused by these acid forming ions. The source of sulfur is probably fossil fuels, including both petroleum and coal. The sulfur is oxidized in combustion and forms sulfuric acid in precipitation. The nitrate is probably fixed by automobiles.

The effects of acid rains are many and important. The acidity is great enough to erode limestone and cement; it is also high enough to affect lakes and streams and to cause serious effects on terrestrial ecosystems. In southern Norway it is reported that the pH of streams has been lowered to the point of eliminating salmon runs (Klein, 1971). Likens and his colleagues (1972) report data suggesting that the acidity of Lake Michigan, the Illinois River, possibly the Ohio River, and the Mississippi has increased in the last 50 to 75 years. But the most important effects, as yet unmeasured in the United States are on the uplands. Acid rains leach nutrients from leaves and other tissues of plants. Weak acid is also commonly used to extract nutrients from soils. A decade or more of highly acid rains must be assumed to have had effects on nutrient cycles in terrestrial systems in the Northeast, including both forests and agriculture. Continued and increasingly acid rain might reasonably be expected to reduce net production of plants regionally making a major step toward the biotic impoverishment of a segment of a continent. A 10–20 percent reduction in net primary productivity for the region would be difficult to detect in less than several years. Such a reduction may be a reality now; it will be surprising if it is not demonstrated clearly within the next decade. The fact that the effects are diffuse does not diminish their importance. A 10 percent reduction in the net primary production of the vegetation of the New England States would be a loss of solar energy equivalent to the output of 15 1,000 megawatt reactors operating at full capacity.

Solutions to the acid rains problem are elusive. The sources of the sulfur and nitrogen probably extend as far west as Chicago and south to the Gulf States. The possibility of shifting to low sulfur fuels throughout any significant part of this area seems remote in view of the mounting shortage of oil and the shift to coal. An early reduction in the consumption of fossil fuels, however necessary, scarcely appears possible.

The prospect for the Northeast is for continued, perhaps increasingly, acid rains that will levy a tax on all, but an especially heavy tax on those who gain their livelihoods directly from forestry, agriculture, fishing, or related industries. It is a most insidious and regressive tax taken from a resource that should not be available for compromise in the endless series of "tradeoffs" made in support of the classical forms of growth. This is a part of the uncounted costs of the growth we have experienced to date that has led to a nonbiotic energy flux

over the United States of 1.67 kwh/m^2/year. It is one sign that we are over developed—that we not only cannot sustain further growth in the current pattern but must plan now for a substantial revision in the pattern and intensity of our activities.

Solar energy is the only long-term source of energy available now for support of man. Within the next decades we can expect worldwide human demands on the flux of solar energy fixed in photosynthesis to increase with a doubling time of 10 to 20 years, perhaps less. These demands include food, fuel, fiber, and environmental services. The demands extend not only to plants, they extend to the full range of diversity of the biota. This diversity offers not only stability and predictability of function, but also a wide range of resources to man.

The challenge for us is to recognize the dependence of man on the Earth's biota and to bend our phenomenal technology resources to see that the biota is not only preserved but that its support for man is enhanced in the most energetically efficient ways consistent with long continued use. This is not a stance against growth; it is a challenge to redirect growth into new and exciting topics consistent with the facts of a 20th century Earth headed for 7 billion people in about 30 years.

The conclusions seem obvious:

1. The Earth's most important resource is its capacity to fix solar energy through photosynthesis and to use it in support of life. This is the Earth's largest flux of energy; its management must now become a major and increasing concern of governments.

2. Man probably uses directly 5–10 percent of the net primary production of plants; the worldwide changes in the quality of air and water and the reductions in the Earth's biota indicate that he is using all of the rest of that energy in secondary services and is in effect now mining the life of the Earth.

3. Man's use of nonbiotic energy has reached about 5 percent of the magnitude of worldwide net production of plants and secondary effects of its use at that level are having serious toxic effects on the Earth's biota, probably reducing overall the fixation of solar energy and its availability in support of man.

4. Growth in the use of fossil fuels and other energy sources will probably be limited in the next decades by the problems of supply and distribution, forcing major changes in the technological societies that will include restraint of growth in energy-rich technologies.

5. The inevitable struggles for more energy that are intensifying rapidly now should not be allowed to destroy additional segments of the Earth's capacity for fixing solar energy. National and international policies on energy development and use are needed now with policies on population to avoid increasing conflict and further degradation of biotic energy sources.

6. The assumption that setting standards for toxins on the basis of thresholds for biotic effects will protect the Earth's biota and man is false. There is no way of determining thresholds for the myriad of substances that can be developed and released, no way of controlling releases, no sure way of monitoring for the substances, and no basis for belief that thresholds for effects on natural ecosystems exist. The alternative is, as stated in the Water Pollution Control Act of 1972, preservation of the chemical, physical, and biotic integrity of those areas of the Earth not directly manipulated by man for urban or agricultural uses.

7. The assumption that the environment has an assimilative capacity for all human insults is misleading and inconsistent with the imperative that the Earth's biota be preserved for continuous use by man. An assimilative capacity for organic matter or heat does not imply an assimilative capacity for mercury, lead, or other substances that may accompany the organic matter. The evidence is overwhelming that man has already exceeded the assimilative capacity of the biosphere for CO_2, chlorinated hydrocarbon pesticides, PCB's, dust and possibly fossil fuel energy. Assimilative capacity is a useful concept only within those areas of the Earth that man determines that he will manage intensively.

8. Economic principles are an insufficient basis for management of the biosphere or such large segments of it as the United States controls. The limits of the Earth can be accommodated by recognization of the fact that the biosphere is a series of interacting units, oceans, forests, estuaries, cities, agricultural

units, each of which has definable characteristics including interactions with other units. Some, such as the oceans, cannot be managed intensively; others such as cities and agricultural regions, must be. The design and management of these units is an essential topic for science and government. It is encouraging that our laws are now beginning to reflect in their objectives some of the realities of the biosphere.

9. The pattern of change necessary in the design of human activities is clear. The further diffusion of toxic influences around the globe must be checked. A certain amount of retrenchment and repair is necessary to assure the stability of biotic resources. Cities cannot be allowed to dispose of wastes in the oceans; fresh water supplies, nutrient elements, and mineral resources are to be conserved and recycled; estuaries and coastal waters cannot be used for cooling power plants or usurped for other industrial uses: they are essential to maintenance of the oceanic biota, including especially the fisheries.

10. These changes in perspective and function of government can come only with a major change in objectives, away from the attractive, even beguiling, concept that economic growth will solve all problems and toward a recognition that the Earth's basic resources of life and energy are finite. The transition requires major support from science, from the educational establishment, and from legislative bodies. Private enterprise cannot be expected to make these innovations. Government must lead by providing the domestic climate and resources for the massive research and educational needs that such a transition requires. We should at the moment be building at least two national laboratories, one in the East and one in the West to address directly the questions of how to reconcile the needs of 20th-century man with the facts of a living but finite Earth. Instead we are watching the dismantling of science. We would be terrified, if we were thoughtful.

11. The inevitable restriction of growth in energy-dense activities does not restrict growth in all segments of society. On the contrary the problems present an intellectual challenge unprecedented in history. We have now a great new freedom to examine in detail the enduring question of what man's most rewarding circumstances might be. On these topics growth has barely begun.

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TABLE 1.—*World average rates of increase for the period 1951–66 for selected aspects of human activity related to food production (SCEP 1970).*

	Percentage increase
Food	34
Tractors	63
Phosphates	75
Nitrates	146
Pesticides	300

TABLE 2.—WORLD ENERGY CONSUMPTION IN 1967 (ADAPTED FROM SCEP 1970, P. 294)

[10^{12} kWh(t)]

	Coal	Petroleum	Gas	Water [1]	Nuclear	Overall
Developed countries:						
United States	3.52	6.33	5.58	0.22	0.03	15.68
Canada	.18	.63	.38	.13		1.32
Western Europe	3.67	4.42	.33	.32	.09	8.83
Eastern Europe	2.42	.37	.26	.01		3.06
U.S.S.R.	3.27	2.23	1.66	.09	(2)	7.45
Japan	.61	1.11	.02	.07		1.81
Oceania	.26	.24		.02		.52
Total	14.13	15.33	8.32	.86	[3] .12	38.67
Developing countries:						
Communist Asia	1.97	.13		.04		2.14
Other Asia (excluding Japan)	.76	.85	0.12	.03		1.76
Africa	.43	.29	.02	.02		.76
Other America	.10	1.14	.33	.06		1.63
Total	3.26	2.41	.47	.15		6.29
World total	17.39	17.74	8.70	1.01	[2] 0.12	44.96

[1] Hydroelectricity is converted from kWh(e) production figures in table 13 of United Nations, World Energy Supplies, as follows:

$$\text{kWh(t)} = \left[\frac{3{,}412\ \text{Btu}}{\text{kWh(e)}}\ \frac{\text{kWh(t)}}{3{,}412\ \text{Btu}}\right] \text{kWh(e)} = [1]\text{kWh(e)}$$

[2] Not available.

[3] Nuclear totals exclude U.S.S.R. for which separate data are not available.

Note: U.N. figures are in million metric tons of coal equivalent The energy contained within 1,000 generated kWh(e) of electricity is equated by the U.N. to 0.125 metric ton coal equivalent. Since the energy content of 1 kWn(e) = the theoretical 3,412 Btu, therefore, $3{,}412 \times 10^6$ Btu = 0.125 m.t.c.e. = 27.3×10^6 Btu.

TABLE 3.—NET PRIMARY PRODUCTION OF THE EARTH. NET PRODUCTION IS THE AMOUNT OF ENERGY OR ORGANIC MATTER AVAILABLE FROM PLANTS TO SUPPORT ANIMALS (INCLUDING MAN) AND ORGANISMS OF DECAY

	10^9T C/yr	10^{12}kWh/yr
Continental:		
Tropical ra nforest	15.3	162.0
Tropical seasonal forest	5.1	55.0
Temperate evergreen forest	2.9	36.0
Temperate deciduous forest	3.8	45.0
Boreal forest	4.3	53.0
Woodlands and shrublands	2.2	27.0
Savanna	4.7	49.0
Temperate grasslands	2.0	21.0
Tundra	.5	5.8
Deserts scrub	.6	7.0
Rock, ice and sand	.04	.3
Cultivated land	4.1	43.0
Swamp and marsh	2.2	23.0
Lake and stream	.6	7.0
Total	48.3	534.0
Marine:		
Open ocean	18.9	237.0
Upwelling	.1	1.2
Continental shelf	4.3	50.0
Algal beds	.5	5.8
Estuaries	1.1	12.8
Total	24.9	307.0
World total	73.2	841.0

Source: Adapted from Whittaker and Likens 1973.

TABLE 4.—THE FLUX AND AVERAGE DENSITY OF ENERGY WORDLWIDE

Source of energy	Wordlwide flux kWh/yr	Density kWh/m²/yr
Solar energy: Top of atmosphere	156×10^{16}	3.05×10^{3}
Net production of plants:		
World	841×10^{12}	1.4
Temperature forests and agriculture		10–21
Nonbiotic energy:		
World (1967) [2]	44.9×10^{12}	[1] 0.880 [3] 0.301
United States (1967) [2]	15.6×10^{12}	1.67
Manhattan		[4] $\sim 2.4 \times 10^{3}$
Kings (Brooklyn)		[4] $\sim 1.36 \times 10^{3}$

[1] Worldwide.
[2] Man's Impact on the Global Environment (SCEP), MIT Press, 1970, p. 294.
[3] Land only.
[4] Estimated on basis of per capita use of energy in United States.

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A Model for a Steady-State Economy

Herman E. Daly*

"More and more people are coming to realize that the growth of material wealth, which the British industrial revolution set going, and which the modern British-made ideology has presented as being mankind's proper paramount objective, cannot in truth be 'the wave of the future.' Nature is going to compel posterity to revert to a stable state on the material plane and to turn to the realm of the spirit for satisfying man's hunger for infinity."

--Arnold Toynbee, *The Observer* June 11, 1972

I. Introduction

This statement by Toynbee indicates two propositions of massive importance: (1) our economy must, sooner or later, conform to a steady state in its physical dimensions of population and stock of artifacts--i.e. in its stocks of endosomatic and exosomatic capital; (2) our pursuit of the infinite must take place in the realm of the infinite which is spiritual, not material. The main purpose of this article is to develop the first proposition and to suggest a "prescriptive model" for institutionalizing the steady state. But the second proposition is closely related to the first and this relationship requires some preliminary discussion.

Man's physical existence is everywhere subject to the laws of steady-state open systems. The entire ecosystem of which man is a part is a steady-state open system, the living organism itself over any short run period is a steady-state open system, as is a population of organisms when in ecological equilibrium. Of course the qualitative nature of the steady state evolves over the long run--organisms

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A fuller treatment of some of the ideas here discussed will be found in Herman E. Daly, editor, *Toward a Steady-State Economy*, W. H. Freeman Co., San Francisco, 1973.

grow old, populations evolve, and entire ecosystems undergo succession. Likewise a steady-state economy would evolve qualitatively in response to technological and moral mutations. As a result of such qualitative evolution it may become both possible and desirable to change the quantitative dimensions of the steady state--to move to a different level of stocks. But quantitative growth (or decline) would then be a temporary, self-conscious, adjustment process of moving from one steady state to another. Continuous, automatic, quantitative growth, far from being the norm of a healthy economy, is ruled out. This contrasts vividly with the prevailing economy of high mass consumption, characterized by W. W. Rostow in the following words: "Growth becomes its normal condition. Compound interest becomes built, as it were, into its habits and institutional structure."* But the solution has become the problem. Our habits and institutions must be weaned away from their addiction to compound interest.

To attempt to redesign the world so as to allow for unlimited physical growth is sheer hubris. Yet man's craving for the infinite has been corrupted by the temptation to satisfy this hunger in the material realm. Turn these stones into bread, says Satan, and modern man sets to it, even to the literal extent of devising energy-intensive schemes to grind up ordinary rock for minerals. But Jesus's answer to the same temptation was that man does not live by bread alone. The object of economic activity is to have enough bread, not infinite bread, not a world turned into bread, not even vast storehouses full of bread. The infinite hunger of man, his moral and spiritual hunger, is not to be satisfied, is indeed exacerbated, by the current demonic madness of producing more and more things for more and more people, world without end. Modern man has an infinite itch, but he

*The Stages of Economic Growth, Cambridge, England, Cambridge University Press, 1960, p. 7.

is scratching in the wrong place, and his frenetic material clawing is drawing blood from the life-sustaining circulatory systems of the biosphere.

It is necessary to be clear on the paramount importance of the moral issue contained in the second proposition. We could opt to destroy the spaceship in a scratching orgy of procreation and consumption. The only arguments against doing this are religious and ethical: the obligation of stewardship for God's creation, the extention of brotherhood to future generations, and of some appropriate degree of brotherhood to sub-human life. Furthermore, although moral and social limits to growth are less recognizable than biophysical limits, they are likely to be much more severe. For example, the social problem of safeguarding plutonium from immoral uses and consequences is a more stringent limit to breeder reactor usage than is the physical constraint of thermal pollution. The apparent willingness of many to push the commercialization of a technology so dangerous that in Nobel Laureate Hannes Alfven's words, "no acts of God can be permitted," and that is not even insurable by market criteria, is an impressive index of the strength of the growth idolatry. It is simply not true that there is no alternative for confronting the "energy shortage". It is true, however, that the obvious alternatives of solar energy, improved use of coal, and perhaps fusion, would probably require higher energy prices and a period of stable consumption. Stockholders would no longer enjoy a growth boom. Is that so terrible that it must be avoided at the cost of a Faustian bargain with the god of the subterranean world of the dead, and his namesake, Plutonium? To describe a Plutonium Plutocracy would strain the horrorific vision of a Dante! Yet "see no evil" continues to be the official attitude and we hear soothing doubletalk about "non-credible accidents" and "implausible" acts of sabotage at the same time we are told that the Price-Anderson Act (limiting

accident liability) is necessary because fission power is too risky for private enterprise!

It will be objected that many people today do not yet have enough bread. Surely brotherhood requires more growth, including crash development of atomic power. But past growth in aggregate bread has done little for these people, since distribution has remained very unequal, and since population has grown rapidly, especially the poorer populations of the world. Distribution is a moral problem, as is population control, and we lack the moral resources to solve these problems because our limited energies have been overwhelmingly devoted to material growth, while morality has been relegated to the status of pre-scientific superstition. And not just in the United States. Witness the Soviet's negative response to Alexander Solzhenitsyn's advocacy of "ethical socialism" or "ethics first, economics afterward." The following passage from his Cancer Ward tells the story of both the USA and USSR.

> "When we have enough loaves of white bread to crush them under our heels, when we have enough milk to choke us, we still won't be in the least happy. But if we share the things we don't have enough of, we can be happy today! If we care only about 'happiness' and about reproducing our species, we shall merely crowd the earth senselessly and create a terrifying society. . ."

The Biblical admonition, "Seek ye first the kingdom of God and his righteousness, and all these things will be added unto you," has been inverted--"add unto yourselves more of all these things, and righteousness can go seek itself." The sins of present injustice will be washed away in a sea of future abundance that is revealed to us by the amazing grace of compound interest. We thought we could grow our way out of poverty and injustice, but we were wrong. There is just not room for that much growth, even on the doubtful assumption that growth tends to lessen poverty. We have chased the infinite in the limited material realm, and

have accepted shamefully modest limits in the infinite moral realm. Our present economic institutions are designed in harmony with this double mistake. To reverse the double mistake, to achieve a political economy of biophysical equilibrium and moral growth, or for short a steady-state economy, will require radical institutional changes as well as a paradigm shift in economic theory.

The current economic paradigm begins with non-physical parameters (technology, preferences, and distribution of wealth and income are all taken as "givens"), and then inquires how the physical variables of quantities produced and resources used must be adjusted to fit an equilibrium (or an "equilibrium rate of growth") determined by these non-physical parameters. The non-physical conditions are considered to be autonomous, while the physical conditions are accommodating. The new paradigm, however, must begin with physical parameters (a finite world, a complex ecosystem, the laws of thermodynamics) and inquire how the non-physical variables of technology, distribution, and life styles can be brought into a feasible and just equilibrium with the complex biophysical system of which we are a part. The physical conditions become autonomous and the non-physical patterns of economic life assume the accommodating role.

II. Three Institutions for a Steady-State Economy

The guiding design principle for the three institutions is to provide the necessary social control with a minimum sacrifice of personal freedom, to provide macro-stability while allowing for micro-variability, to combine the macro-static with the micro-dynamic. To do otherwise, to aim for micro-stability and control is likely to be self-defeating and result in macro-instability as the capacities for spontaneous coordination, adjustment, and mutation (which always occur on the micro level) are stifled by central planning with its inevitable rigidities and information losses. The micro is the domain of indeterminacy, novelty, and freedom.

The macro or aggregate is the domain of determinacy, predictability, and control. We should strive for macro control and avoid micro meddling. A second design principle, closely related to the first, is to maintain considerable slack between the actual environmental load and the maximum carrying capacity. The closer the actual approaches the maximum the less is the margin for error, and the more rigorous, finely-tuned, and micro-oriented our controls will have to be. We lack the knowledge and ability to assume detailed control of the spaceship, so therefore we must leave it on "automatic pilot," as it has been for eons. But the automatic pilot only works when the actual load is small relative to the conceivable maximum.* A third design principle, important for making the transition, is to build in the ability to tighten constraints gradually.

The kinds of institutions required follow directly from the definition of a steady-state economy: constant stocks of people and physical wealth maintained at some desirable chosen level by a low rate of throughput. We need: (1) an institution for stabilizing population (the Boulding marketable license plan); (2) an institution for stabilizing wealth and keeping throughput below ecological limits (marketable depletion quotas auctioned by the government); (3) a distributist institution limiting the degree of inequality in the distribution of the constant stocks among the constant population (maximum and minimum limits to personal wealth and income).

Let us outline briefly how each institution might function, and how they interrelate.

A. Distributist Institution. The critical institution is likely to be the minimum and maximum limits on wealth and income. Without this, private property

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*To the optimistic micro meddlers who do not believe in "automatic pilots" or "invisible hands" and thus want to assume detailed control of spaceship and crew, I can only quote Elisa Dolittle's reply to Mr. 'iggins, "without your pulling it the tide comes in, without your twirling it the earth will spin, without your pushing them the clouds roll by, and if they can do it without you, ducky, so can I!" Skeptics who totally deny the "invisible hand" should read Eastern European economists' discussions of overcentralization and the resulting waste of resources.

and the whole market economy lose their moral basis, and there would be no strong case for extending the market to cover birth quotas and depletion quotas as a means of institutionalizing environmental limits. Exchange relations are mutually beneficial among relative equals. Exchange between the powerful and the powerless is often only nominally voluntary and can easily be a mask for exploitation, especially in the labor market, as Marx has shown.

There is considerable political support for a minimum income financed by a negative income tax, as an alternative to bureaucratic welfare programs. There is no such support for a maximum income or for either maximum or minimum wealth limits. In the growth paradigm there need be no upper limit. But in the steady-state paradigm there is an upper limit to the total, and the higher the minimum per capita share, the lower must be the maximum per capita share. A minimum wealth limit may not be feasible, since one can always spend his wealth, and could hardly expect to have it restored year after year. The minimum income would be sufficient. But maximum limits on wealth and income are both necessary, since wealth and income are largely interchangeable, and since beyond some point the concentration of wealth becomes inconsistent with both a market economy and political democracy. John Stuart Mill put the issue very well:

> "Private property, in every defense made of it, is supposed to mean the guarantee to individuals of the fruits of their own labor and abstinence. The guarantee to them of the fruits of the labor and abstinence of others, transmitted to them without any merit or exertion of their own, is not of the essence of the institution, but a mere incidental consequence which, when it reaches a certain height, does not promote, but conflicts with, the ends which render private property legitimate." (Principles of Political Economy, Book II, Chapter I, "Of Property")

According to Mill private property is legitimated as a bastion against exploitation. But this is true only if everyone owns some minimum amount. Otherwise private property, when some own a great deal of it and others have very little,

becomes the very <u>instrument</u> of exploitation, rather than a guarantee against it. It is implicit in this view that private property is legitimate only if there is some distributist institution (like, for example, the Jubilee year of the Old Testament) which keeps inequality of wealth within some justifiable limits. Such an institution is now lacking. The proposed institution of maximum wealth and income, plus minimum income limits would remedy this severe defect and make private property legitimate again. Also it would go a long way toward legitimating the free market, since most of our blundering interference with the price system (e.g. farm program, minimum wage, rent controls) has as its goal an equalizing alteration in the distribution of income and wealth. Thus such a distributist policy is based on impeccably respectable premises: private property, the free market, opposition to welfare bureaucracies and centralized control. It also heeds the radicals' call of "power to the people" since it puts the source of power, namely property, in the hands of the many people, rather than in the hands of the few capitalist plutocrats and socialist bureaucrats.

Maximum income and wealth would remove many of the incentives to monopolistic practices. Why conspire to corner markets, fix prices, etc., if you cannot keep the loot? As for labor, the minimum income would enable the outlawing of strikes, which are rapidly becoming intolerable. Unions would not be needed as a means of confronting the power of concentrated wealth, since wealth would no longer be concentrated. Indeed, the workers would have a share of it and thus would not be at the mercy of an employer. In addition, some limit on corporate size would be needed, or else a requirement that all corporate profits be distributed as dividends to stockholders.

With no large concentrations in wealth and income, savings would be smaller and would truly represent abstinence from consumption rather than surplus remaining

after satiation. There would be less expansionary pressure from large amounts of capital seeking ever new ways to grow exponentially.

The minimum income could be financed out of general revenues, which, in addition to a progressive income tax within the income limits, would also include revenues from the depletion quota auction, and 100% marginal tax rates on wealth and income above the limits. Upon reaching the maximum most people would devote their further energies to non-economic pursuits, so the latter revenues would be small. But the opportunities thus forgone by the wealthy are available to the not-so wealthy, who will still be paying taxes on their increased earnings. The effect on incentive will be negative at the top, but positive at lower levels leading to a broader participation in running the economy. There may also be an increase in public service. As Jonathan Swift argued:

> "In all well-instituted commonwealths, care has been taken to limit men's possessions; which is done for many reasons, and, among the rest, for one which, perhaps, is not often considered; that when bounds are set to men's desires, after they have acquired as much as the laws will permit them, their private interest is at an end, and they have nothing to do but to take care of the public." ("Thoughts on Various Subjects," in *The Literature of England*, G. B. Woods et. al., eds., Scott, Foreman and Co. 1958, p. 1003)

B. *Marketable Licenses to have children.* For maintaining a constant population an ingenious institution has been proposed by Kenneth Boulding. Unfortunately it has been treated more as a joke than as a serious proposal. The idea is to issue directly to individuals licenses to have children. Each person receives certificates in an amount permitting 1.1 children, or each couple at marriage receives certificates permitting 2.2 children, or whatever number corresponds to replacement fertility. The licenses can be bought and sold on a free market. Thus macro-stability is attained, micro-variability is permitted. Furthermore those having more than two children must pay for an extra license, those who have fewer than two children, receive payment for their unused license certificates. The right to have

children is distributed equally. Market supply and demand then redistribute these rights according to differing preferences and abilities to pay. People who do not or can not have children are rewarded financially. Poeple who wish to have more than two are penalized financially. And the subsidies and penalities are handled by the market with no government bureaucracy.

A slight amendment to the plan might be to grant 1.0 certificates to each individual and have these refer not to births but to "survivals". If someone dies before he has a child then his certificate becomes a part of his estate and is willed to someone else, e.g. his parents, who either use it to have another child, or sell it to someone else. The advantage of this modification is that it offsets existing class differentials in infant and child mortality. Without the modification a poor family desiring two children could end up with two infant deaths and no certificates. The best plan of course is to eliminate class differences in mortality, but in the meantime this modification may make the plan initially easier to accept. Indeed, even in the absence of class differentials the modification has the advantage of building in a "guarantee".

Let us dispose of two common objections to the plan. First it is argued that it is unjust because the rich have an advantage. Of course the rich always have an advantage, but is their advantage increased or decreased in Boulding's plan? Clearly it is decreased. The effect of the plan on income distribution is equalizing because (1) the new marketable asset is distributed equally, (2) as the rich have more children their family per capita incomes are lowered, as the poor have fewer their family per capita incomes increase. Also from the point of view of the children there is something to be said for increasing the probability that they will be born richer rather than poorer. Whatever injustice there is in the plan stems from the existence of rich and poor, not from Boulding's plan which actually reduces the degree of injustice. Furthermore, income and wealth distribution are

to be controlled by a separate institution, discussed above, so that in the overall system this objection is more fully and directly met.

A more reasonable objection raises the problem of enforcement. What to do with law-breaking parents and their illegal children? What do we do will illegal children today? One possibility is to put the children up for adoption and encourage adoption by paying the adopting parents the market value, plus subsidy if need be, for their license, thus retiring a license from circulation to compensate for the child born without a license. Like any other law breakers the offending parents are subject to punishment. The punishment need not be drastic--e.g. a year's paid labor in a public child care center. Of course if everyone breaks a law no law can be enforced. The plan presupposes the acceptance by a large segment of the public of the morality and necessity of the law. It also presupposes widespread knowledge of contraceptive practices, and legalized abortion. But these presuppositions would apply to any institution of population control, except the most coercive.

Choice may be influenced in two ways: by acting on or "rigging" the objective conditions of choice (prices and incomes in a broad sense), or by manipulating the subjective conditions of choice (preferences). Boulding's plan imposes straightforward objective constraints and does not presumptuously attempt to manipulate peoples' preferences. Preference changes due to individual example and moral conversion are in no way ruled out. If preferences should change so that, on the average, the population desired replacement fertility, the price of a certificate would approach zero and the objective constraint would automatically vanish. The current decline in the birth rate has perhaps already led to such a state. (Conceivably the birth rate could fall too low, in which case the certificate price would become negative and the whole institution would work in reverse!) The moral basis of the plan is that everyone is treated equally, yet there is no

insistence upon conformity of preferences, the latter being the great drawback of "voluntary" plans which rely on official moral suasion and Madison Avenue techniques. Some people, God bless them, will never be persuaded, and their individual non-conformity wrecks the moral basis (equal treatment) of "voluntary" programs.

There is an understandable reluctance to couple money and reproduction--somehow it seems to profane life. Yet life is physically coupled to increasingly scarce resources, and resources are coupled to money. If population growth and economic growth continue, then even free resources such as breathable air will either become coupled to money and subject to price, or allocated by a harsher and less efficient means. Once we accept the fact that the price system is the most efficient mechanism for sharing and rationing the right to scarce life-sustaining and life-enhancing resources, then perhaps rather than "money profaning life" we will find that "life sanctifies money". It is not the exchange relationship that debases life, it is the underlying inequality in wealth and income beyond any functional or ethical justification, that loads the terms of free exchange against the poor. The same inequality also debases the "gift relationship" since it reduces the poor to the status of a perpetual dependent, and the rich to the status of a weary and grumbling patron. Thus gift as well as exchange relationships require limits to the degree of inequality if they are not to subvert their legitimate ends.

C. Depletion Quotas. The strategic point at which to impose control seems to me to be the rate of depletion of material resources, particularly non-renewable resources. If we limit aggregate depletion, then by the law of conservation of matter and energy, we will also indirectly limit aggregate pollution. Entropy is at its minimum at the input (depletion) end of the throughput pipeline, and at its maximum at the output (pollution) end. Therefore it is physically easier to

monitor and control depletion than pollution--there are fewer mines, wells, and ports than there are smokestacks, garbage dumps, and drainpipes, not to mention such diffuse emission sources as run-off of insecticides and fertilizers from fields into rivers and lakes, and auto exhausts. Given that there is more leverage in intervening at the input end, should we intervene by way of taxes or quotas? Quotas, if they are auctioned by the government rather than allocated on non-market criteria, have an important net advantage over taxes in that they definitely limit aggregate throughput, which is the quantity to be controlled. Taxes exert only an indirect and very uncertain limit. It is quite true that given a demand curve, a price plus a tax determines a quantity. But demand curves shift and are subject to great errors in estimation, even if stable. Demand curves for resources could shift up as a result of population increase, change in tastes, increase in income, etc. Every time we increase a price (internalize an externality) we also increase an income, so that in the aggregate the economy can still purchase exactly as much as before. The government taxes throughput and then spends the tax. On what? On throughput. If government expenditures on each category of throughput were equal to the revenues received from taxing that same category, then the limit on throughput would be largely cancelled out. If the government taxes resource-intensive items and spends on time-intensive items there will be a one-shot reduction in aggregate physical throughput, but not a limit to its future growth. A credit expansion by the banking sector, an increase in velocity of circulation of money, or deficit spending by the government for other purposes could easily offset even the short-run reduction induced by taxes. Taxes can influence the amount of depletion and pollution (throughput) per unit of GNP, but taxes provide no limit to the increase in the number of units of GNP, and thus no limit to aggregate throughput. The fact that a tax levied on a single resource could usually reduce

the throughput of that resource very substantially, should not mislead us into thinking that a general tax on all resources will reduce aggregate throughput (fallacy of composition). It is quantity that affects the ecosystem, not price, and therefore it is ecologically safer to let errors and unexpected shifts in demand result in price fluctuations rather than in quantity fluctuations. Hence quotas.

Pollution taxes also provide a much weaker inducement to resource-saving technological progress than do depletion quotas, since in the former scheme resource prices do not necessarily have to rise, and may even fall. The inducement of pollution taxes is to "pollution avoidance", and thus to recycling. But increased competition from recycling industries, instead of reducing depletion, might spur the extractive industries to even greater competetive efforts. Intensified search and the development of technologies with still larger jaws (e.g. strip mining) could speed up the rate of depletion and thereby lower resource prices. Thus new extraction might once again become competetive with recycling, leading to less recycling and more depletion--exactly what we wish to avoid. This perverse effect could not happen under a depletion quota system.

The usual recommendation of "pollution taxes" would seem, if the above is correct, to intervene at the wrong end with the wrong policy tool. Intervention by pollution taxes also tends to be micro control, rather than macro. There are, however, limits to the ability of depletion quotas to influence the qualitative nature and spatial location of pollution, and at this fine-tuning level pollution taxes would be a useful supplement.

How might a depletion quota system function? Let there be quotas set on new depletion on each of the basic resources, both renewable and non-renewable, during a given time period. Let legal rights to deplete up to the amount of the quota

for each resource be auctioned off by the government, at the beginning of each time period, in conveniently divisible units, to private firms, individuals, and public enterprises. After purchase from the government the quota rights are freely transferrable by sale or gift, and can be retained for use in subsequent time periods. As population growth and economic growth press against resources the prices of the depletion quotas will be driven higher and higher. Reduction of quotas to lower levels in the interest of conservation of non-renewables and sustainable exploitation of renewables would drive the price of the quotas still higher. The increasing windfall rents resulting from increasing pressure of demand on fixed supply would be captured by the government through the auctioning of the depletion rights. The government spends the revenues, let us say, by paying a social dividend. Even though the monetary flow is therefore undiminished, the real flow (throughput) has been physically limited by the resource quotas. All prices of resources and of goods increase, with the prices of resource-intensive goods increasing relatively more. Total resource consumption (depletion) is reduced. Moreover, by the law of conservation of matter-energy, if ultimate inputs are reduced so must ultimate outputs (pollution) be reduced. The aggregate throughput is reduced and with it the gross stress it puts on the ecosystem.

With depletion now more expensive and with higher prices on final goods, recycling becomes more profitable. As recycling increases, effluents are reduced even more. Also higher prices make consumers more interested in durability and careful maintenance of wealth. The extra burden to the poor of increased prices can be more than offset via the distributist institution. Most importantly there is now a strong price incentive to develop new resource-saving technologies and patterns of consumption. If there is any static efficiency loss in setting the rate of depletion outside the market (a doubtful point), it seems to be more than

offset by the dynamic benefits of greater inducements to resource-saving technological progress.

The adjustment of depletion and pollution flows (throughput) to long run ecologically sustainable levels can be effected gradually. In the first year depletion quotas could be set at last year's levels, and if necessary gradually reduced by say 2% per year until we reach an equilibrium level of stocks of wealth requiring that "optimal" throughput for its maintenance. Thereafter the constant stock will be maintained by the constant throughput. As we gradually exhaust non-renewable resources their quotas will approach zero and recycling will become the only source of inputs. By this time, presumably, the ever-rising price of the resource would have induced a recycling technology. Without quotas this resource exhaustion need not be gradual. Also, without quotas, the incentive to develop the new technology is less, since one must face the uncertainty that some newly discovered reserves will lower resource prices and make the resource-saving technology temporarily uneconomic. When the rate of depletion becomes a social parameter it can be taken as known, and uncertainty will be less. Discoveries of new reserves will increase the length of time until exhaustion, rather than lowering the price.

With depletion quotas the aggregate rate of depletion becomes a social decision. This can be regarded as the correction of a market failure. For renewable resources quotas can be set at a calculated optimum sustainable yield or maximum rent, thus correcting the market failure of over-exploitation. The quota on renewables must be such as to avoid "eating into our capital." For privately owned and well-managed renewable resources the quotas would be redundant, and could be dispensed with. Since with non-renewables mankind is always eating his capital the rate of depletion should be a collective decision based largely on value judgments--once we are below

ecological disaster thresholds. But two considerations argue for lower rates of depletion and higher prices than now prevail: first the conservationists moral concern about future generations, and secondly the idea that resource-saving technology can be induced by high resource prices. The rate of depletion of the stock of terrestrial low entropy is fundamentally a moral decision and should be decided on grounds of ethical desirability (stewardship), not technological possibility or present value calculations of profitability. By fixing the rate of depletion we force technology to focus more on the flow sources of solar energy and renewable resources. The solar flux cannot be increased in the present at the expense of the future. Thus let technology devote itself to learning how to live off our solar income, rather than our terrestrial capital. Such advances will benefit all generations, not just the present.

The issue is clarified by the following simple, yet insightful observation by Georgescu-Roegen:

> "Man's natural dowry, as we all know, consists of two essentially distinct elements: (1) The stock of low entropy on or within the globe, and (2) the flow of solar energy, which slowly but steadily diminishes in intensity with the entropic degradation of the sun. But the crucial point for the population problem as well as for any reasonable speculations about the future exasomatic evolution of mankind is the relative importance of these two elements. For as surprising as it may seem, the entire stock of natural resources is not worth more than a few days of sunlight."*

The exosomatic or technological evolution of mankind over the last two centuries has almost entirely depended on the less abundant stock source of man's "natural dowry", thus shifting our dependence away from the more abundant solar flow. How ironic, then, to be told by growth boosters that technical progress has reduced man's dependence on natural resources! But this does not mean that technical evolution cannot be redirected. Indeed, the main goal of the depletion quota plan is to turn technical change away from increasing dependence on the terrestrial stock and toward the more abundant flow of solar energy and renewable resources. As the

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*Nicholas Georgescu-Roegen, The Entropy Law and the Economic Process, Harvard University Press, 1971, p. 21.

stock becomes relatively more expensive it will be used less in direct consumption and more for investment in "work gates" which increase our ability to tap the solar flow. Instead of taking long run technical evolution as a parameter to which the short run variables of price and quantity continually adjust, the idea is to take short run quantities (and hence prices) as a social parameter to be set so as to induce a direction of technical evolution more in harmony with mankind's long run interests.

The depletion quota plan should appeal both to technological optimists and pessimists. The pessimist should be pleased by the conservation effect of the quotas, while the optimist should be pleased by the price inducement to resource-saving technology. The optimist tells us not to worry about running out of resources because technology embodied in reproducible capital is a nearly perfect substitute for resources. As we run out of anything prices will rise and substitute methods will be found. If one believes this, then how could one object to quotas, which simply increase the scarcity and prices of resources a bit ahead of schedule and more gradually. This plan simply requires the optimist to live up to his faith in technology.

Like the maximum limits on income and wealth, the depletion quotas could also have a trust-busting effect if accompanied by a limit--e.g. no single entity can own more than x percent of the quota rights for a given resource, or more than y percent of the resource owned by the industry of which it is a member. "x" and "y" could be set so as to allow legitimate economies of scale, while curtailing monopoly power.

A further effect of the quota scheme is that relative factor prices would change, with labor becoming cheaper relative to natural resources and capital. This effect by itself would tend to increase employment, which in itself is not a benefit, but

is necessary as long as we maintain as income-through-jobs system of distribution. However, reduced aggregate consumption would tend to reduce employment. If the latter effect predominated a job-sharing reduction in the work week might be needed, or increased reliance on unearned income, such as a social dividend financed out of receipts from the auction of resource quotas, or capital income to the worker resulting from wider distribution of capital ownership. But we have a distributist institution designed to accomplish these ends, which are desirable on their own account.

The actual mechanics of quota auction markets for three or four hundred basic resources would present no great problems. The whole process could be computerized since the function of an auctioneer is purely mechanical. It could be vastly simpler, faster, more decentralized, and less subject to fraud and manipulation than today's stock market. Also, qualitative and locational variation among resources within each category, though ignored at the auction level, will be taken into account in price differentials paid to resource owners.

The depletion quota and birth quota systems bear an obvious analogy. The difference is that the birth quotas are equally distributed and privately held initially, and then redistributed among individuals through the market, while the depletion quotas are collectively held initially and then distributed to individuals by way of an auction market. The revenue derived from birth quotas is private income, the revenue from depletion quotas is public income.

The scheme could and probably must be designed to include imported resources. The same depletion quota right could be required for importation of resources, and thus the market would determine the proportions in which our standard of living is sustained by depletion of national and foreign resources. Imported final goods would now be cheaper relative to national goods, assuming foreigners do not limit

their depletion. Our export goods would now be more expensive relative to the domestic goods of foreign countries. We would tend to a balance of payments deficit. But with a freely fluctuating exchange rate a rise in the price of foreign currencies relative to the dollar would restore equilibrium. It might be objected that limiting our imports of resources will work a hardship on the many underdeveloped countries who export raw materials. This is not clear, because such a policy will also force them to transform their own resources domestically rather than through international trade. Finished goods would not be subject to quotas. Also foreign suppliers of raw materials are treated no differently from domestic suppliers. In any case it is clear that in the long run we are not doing the underdeveloped countries any favor by using up their resource endowment. Sooner or later they will begin to drive a hard bargain for their non-renewable resources, and we had best not be too dependent on them. Eventually population control and environmental protection policies might become preconditions for membership in a new free-trade bloc or common market.

III. Political Feasibility

As of 1973 the political feasibility of these reforms is obviously nil. Nor should it be otherwise, since this suggestion represents a tentative beginning, not a detailed, widely-critiqued, mature proposal. It may contain terrible mistakes. If so critics will discover them, and will suggest remedies and improvements.

But over the medium run of say five to ten years, such institutions may appear less extreme than the physical costs of the trends generated by our current institutions. Consider, for example, that although the President's Commission on Population Growth and the American Future did not advocate a marketable license plan for population control, it did recommend that the nation "welcome and plan

for a stabilized population." Furthermore it listed some criteria for a good stabilization plan. The Commission prefers "a course toward population stabilization which minimizes fluctuation in number of births; minimizes further growth; minimizes change required in reproductive habits and provides adequate time for such changes to be adopted; and maximizes variety and choice in life styles, while minimizing pressures for conformity." On these criteria the marketable license plan scores better than any alternative that I have seen or am able to imagine.

We now have a President's Commission on Materials Policy, and it remains to be seen what they will recommend. Probably they will recognize the need for higher resource prices. From this recognition will follow the intensification of the distribution issue, and the search for the most just and efficient way to raise resource prices. Depletion quotas will surely be discussed, though pollution taxes are likely to be favored initially. Economists have made the case that pollution taxes are superior to direct regulations and to subsidizing pollution abatement. But the alternative of depletion quotas has not yet been widely debated. The 1952 President's Materials Policy Commission (the Paley Commission), though acknowledging that "We share the belief of the American people in the principle of Growth"(their capital G), also went on to make the following enlightened observation, "Whether there may be any unbreakable upper limit to the continuing growth of our economy we do not pretend to know, but it must be a part of our task to examine such limits as present themselves." This would be a good point of departure for the 1972 Commission.

The minimum income part of the distributist institution already has political support. How much support one gets for the maximum income and wealth depends partly on where the limits are set. There are very, very few voters with more

than $100,000 income and $500,000 net worth, and not many citizens who really believe that anything beyond those limits should not be classed as greed rather than need. The same could be said of limits set at one half the above. Exactly where we draw the line is less important than the principle that such lines must be drawn. A widespread recognition of the general closure of growth should increase the appeal of maximum limits and perhaps revive our Populist heritage. If we really want decentralized decision making and participatory democrary rather than a "plutonium-powered corporate kleptocracy," some such limit is essential. Yet there is still ample room for the principle of differential reward for differential effort and contribution. A jealous homogeneity is not the goal.

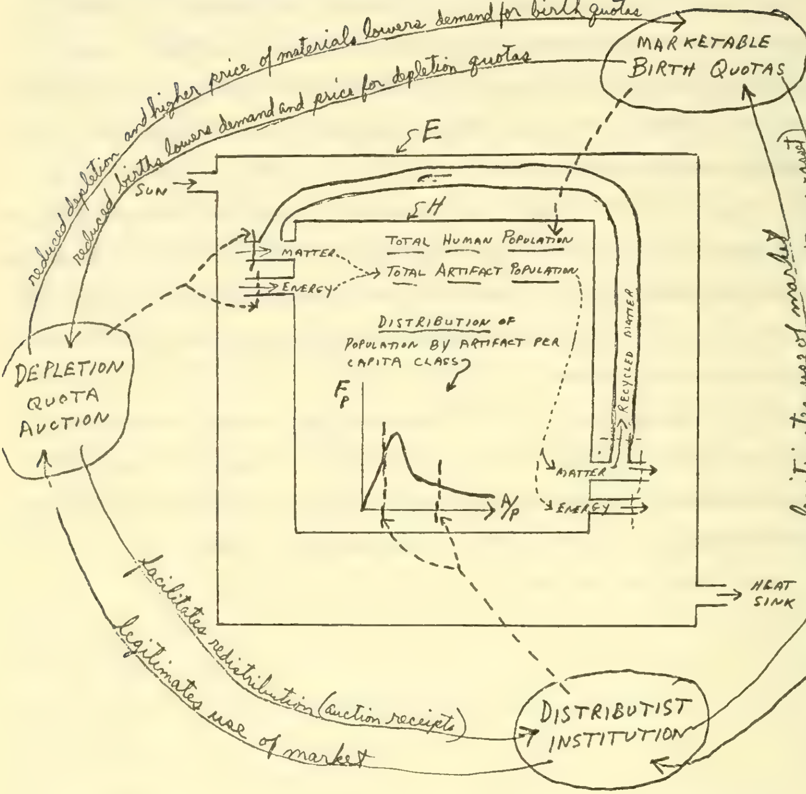
All three institutions are capable of gradual application during the transition to a steady state. The birth quota does not have to be immediately set at replacement, but could begin at existing levels and gradually approach replacement or even lower fertility. Initially the price would be zero, and would rise gradually as the number of certificates issued to each person was cut from say 1.1, to 1.0, to 0.9, or to whatever level is desired. The depletion quotas could likewise be set at present levels, or even at levels corresponding to a slower rate of increase than in the recent past. They could be applied first to those materials in shortest supply, and to those whose wastes are hardest to absorb, and then gradually extended to include nearly all minerals and fossil fuels. Initial prices on quota rights would be low, but then would rise gradually as growth pressed against the fixed quotas, or as quotas were reduced in the interest of conservation. In either case the increased scarcity rent becomes revenue to the government. The distribution limits might begin near the present extremes and slowly close to a more desirable range. The three institutions are amenable to any degree of gradualism one may wish. However the distribution limits must be

tightened faster than the other two if the burden on the poor is to be lightened.

But it is also the case that these institutions could be totally ineffective. Depletion quotas could be endlessly raised on the grounds of national defense, balance of payments, etc. Real estate and construction interests, not to mention the baby food and toy lobby, might convince Congress to keep the supply of birth licenses well above replacement level. People at the maximum income and wealth limit may succeed in raising that limit by spending a great deal of their money on T.V. ads extolling the Unlimited Acquisition of Everything as the very foundation of the American Way of Life. And everything would be the same, and all justified in the sacred name of growth. Nothing will work unless we break our idolatrous committment to material growth.

Thus we are brought back to the all important moral issues with which we began. A physical steady state, if it is to be worth living in, absolutely requires moral growth. Future progress simply must be made in terms of the things that really count, rather than the things that are merely countable.

SCHEMATIC REPRESENTATION



Physical system is within rectangle E. Rectangle H is human subsystem.

Social control system is outside rectangle E.

Points of contact between social control system and physical system are shown ~~in~~ by dotted lines.

RAPID POPULATION GROWTH

Consequences and Policy Implications

VOLUME I
SUMMARY AND RECOMMENDATIONS

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with the support
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Preface

In this book we attempt to define and describe the problems resulting from today's unprecedented rates of human population increase, and to help policymakers understand the implications of these problems. In its entirety the work contains a summary and recommendations (Volume I) and a collection of research papers (Volume II) by scholars representing several disciplines—economics, political science, sociology, demography, education, social ethics and public health. We hope that our conclusions will appeal to a wide audience, but we realize that many potential readers, especially busy and preoccupied government officials, are unlikely to have the time to study the more technical research papers upon which the policy recommendations are based. We have therefore decided that publication should take two forms: a clothbound edition containing both sections of the study, and a low-priced paperback edition of Volume I, the summary and recommendations. The paperback edition of Volume I is a self-contained unit and can be read as such; however, for the interested reader, references are made in the footnotes to the more detailed discussions in Volume II.

Early in 1967 the directors of seven U.S. centers for the study of population agreed that not enough is known about the economic and social effects of rapid population growth. This lack of knowledge has not, however, hindered the development of population policies and programs in a number of countries around the world. Some governments, seeing the specters of famine or of vast armies of unemployed, have moved forthrightly to help their people limit their own fertility. Other national administrations have stalwartly defended the need for more people to fill their empty lands or to provide the human engine for their march toward "national destiny."

Study and research about the physiology and chemistry of the human reproductive system proceed apace. Comparable research on the social and economic, political, and educational consequences of high and sometimes rising birth rates, falling mortality, differing age patterns in changing societies, and what a policymaker can do about these phenomena, has lagged sorely behind the research on demographic and contraceptive aspects of the problems. The center directors asked why this is so and whether something could

be done about it. Dr. Roger Revelle, Director of the Harvard University Center for Population Studies, took the question to the then Administrator of the Agency for International Development, Mr. William S. Gaud, who in turn asked the National Academy of Sciences to design and execute this study. Dr. Frederick Seitz, President of the Academy at that time, appointed the undersigned as a special study committee, and requested Mr. W. Murray Todd, chief staff officer of the Office of the Foreign Secretary, to help in organizing and developing the study.

In the course of this work, two objectives have evolved: First, we have tried to understand some of the consequences (and to a lesser extent some of the determinants) of rapid population growth. We have limited ourselves to relatively short-term and clear-cut issues that are somewhat obvious, because these are the phenomena that concern the most people and about which policymakers must make decisions now.

Second, we have tried to separate some exceedingly complex problems into manageable components. In the past, much of the case for population limitation has rested on the presumed likelihood of exponential growth over rather long periods of time. Apocalyptic visions of the future are based on simple, mathematical extrapolation of present rates of population growth. We have asked a number of students of population to tell us what we really *do* know, on the basis of the carefully collected evidence, and what we *do not* know; their answers are reported in Volume II. From these papers and other evidence we have tried to derive a set of propositions about population growth and to infer some implications for the policymaker; these are contained in Volume I.

We have endeavored to examine the population problem as it affects us now—and for the next 5 to 30 years. The time dimension for any policy action that affects population is very likely to exceed the term of public office of the policymaker or planner. This means that the rationale for public policy on population must be so clear to the citizenry that the policy's life is not dependent upon the term of its political sponsor. Thus we try to make the case for public understanding, wide dissemination of knowledge, free and open discussion of available evidence, and dedication to expanded research.

In our recommendations in Volume I we argue for action to limit population growth now, based on the available evidence and the need to do something with the tools at our disposal to improve the conditions of life for families, by giving parents the means and the incentives to limit their fertility, and to help societies balance their numbers with available food, jobs, education, health services, or resources.

Rapid Population Growth follows two earlier Academy publications, *The Growth of World Population* (1963) and *The Growth of U.S. Population* (1965). It is an extension of our understanding and an expression of the

Academy's continuing sense of obligation to speak forthrightly on this most fundamental problem.

Our work contains statements of opinion as well as fact. We have drawn freely from our contributing authors and from the literature. We recognize that we have a certain bias stemming from our Judeo-Christian tradition and that controversy can surround many aspects of population questions, but our goal has been to approach our subject in a spirit of detachment and humane understanding of the wide range of values with which different societies approach these great issues.

We have attempted to offer policymakers reasoned options and to demonstrate the qualitative as well as the quantitative dimensions of human population change. Current research is accumulating evidence that considerations of individual and family welfare have a direct and immediate impact on the fertility behavior of parents. Equally critical are the long-term considerations of the total number of people in relation to total food supply, resources, land, and the environment that transcend several generations, because they too must be the concern of the planner and policymaker today.

We believe governments need to understand that quantitative and qualitative population questions are bound to force a series of increasingly far-reaching governmental policy decisions and that the longer these decisions are avoided, the more difficult they will become. Our goal is to contribute to the scientific analysis and informed opinion that can lead to intelligent policy formulation and execution in both the public and private sectors.

The Committee

Roger Revelle, Chairman
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Moye Freymann
Oscar Harkavy
Hans Landsberg
Walsh McDermott
Norman Ryder
T. W. Schultz
George Stolnitz
Harold A. Thomas
Samuel Wishik
W. Murray Todd, Staff

I

An Overview of the Problem

In this book we are concerned with the most fundamental event of our times—the enormous growth of the world's population during the last 3 decades, and the prospects for continued growth in the future.

Many people believe, as Malthus did at first, though he later changed his mind, that the numbers of human beings will always increase up to a level set by the available food supply, or by enemies and disease. "Gigantic, inevitable famine stalks in the rear of misery and vice to limit the numbers of mankind." Even though death rates today are lower than they have ever been, and the proportion of the world's human population that is seriously malnourished is probably less than at any time since the Old Stone Age, the belief is widespread that uncontrolled population growth in the earth's poor countries is leading to catastrophe. It is possible, however, to take a different view, based on what we know about the history of human populations and on the behavior of many people at the present time—a view that social inventions will lead to a deliberate limitation of fertility by individual couples.

At the same time the technical potentialities exist, not only to feed all human beings, but greatly to improve the quality of human diets, at least until the end of this century. During the next 20 years no change in human fertility patterns can have much effect on the dimensions of the world food problem. And the natural resources available to present technology are sufficient to allow a vast improvement in the standard of living of all the people who will inhabit the earth 20 to 30 years from now. This is not to say that such an improvement in diets or standard of living will inevitably occur. It will depend on the improvement of social and economic institutions, and on the growth of cooperation and interdependence among the peoples of the world.

Nevertheless, a reduction in present rates of population growth is highly desirable from many points of view, because high fertility and rapid population growth have seriously adverse social and economic effects. A reduction in human fertility is an important component of social and economic development, although such a reduction cannot be a substitute for large capital investments and massive transfers of technology.

Rapid population growth has economic, social, and political effects. It also interacts with public education, health and welfare, and the quality of the environment in which people live. As we shall show, many of these consequences are not well understood, and their magnitude is uncertain. The significance of others is less than is generally believed. Without at this time assigning quantitative values, we may very briefly list the categories of consequences that are usually recognized. In later sections, these consequences are discussed more fully.

Categories of Consequences

Economic Consequences

Rates of population growth in many less developed countries are at least half the rates of economic growth and in some cases almost equal the latter. Chiefly because of the high fertility of these countries, the ratios of children to adults are very high when compared with these ratios in developed countries, and the numbers of young people reaching the age of labor force participation are rapidly increasing. Both of these factors produce serious economic consequences.

Rapid population growth slows down the growth of per capita incomes in less developed countries and tends to perpetuate inequalities of income distribution. It holds down the level of savings and capital investment in the means of production and thereby limits the rate of growth of gross national product. Food supplies and agricultural production must be greatly increased to meet the needs of rapidly growing populations, and this constrains the allocation of resources to other economic and social sectors. The number of persons entering the labor force grows very rapidly. Because the number of people seeking employment is larger than the number of available jobs, unemployment and underemployment are increasingly serious problems. An ever larger number of workers cannot be absorbed in the modern (industrialized) sector. They are forced into unproductive service occupations or back into the traditional (agricultural) sector with its low productivity and bare subsistence wage levels. Large supplies of cheap labor tend to hold back technological change, and industrialization is slowed by mass poverty, which reduces the demand for manufactured goods. Low savings rates and low labor skill inhibit the full development and utilization of natural resources in some countries, while in others the growing populations outrun the levels at which renewable resources can be sustained, and the resource base deteriorates. Widespread poverty, the low productivity of labor, the growing demands for food, and slow industrialization distort and degrade the international trade of the less developed countries.

Social Effects

Large-scale internal migration and rapid urbanization are among the most important social effects of rapid population growth. The growing numbers of children who survive their parents place new strains on intergenerational relationships. Social mobility is impeded by continuing widespread poverty. Because only a fraction of the growing population can be absorbed into the modern sector, the numbers of people in the traditional sector rapidly increase and the gap between the two continually widens. Thus two "nations," one relatively well off and the other backward and poor, exist side by side in the same country.

Political Effects

Political and social conflicts among different ethnic, religious, linguistic, and social groups are greatly worsened by rapid population growth. Political and administrative stresses are increased by the rural-urban migration which is partly caused by this growth, and by increasing demands for government services in health, education, welfare, and other functions. The large proportions of young people, particularly those who are unemployed or have little hope for a satisfactory future, form a disruptive and potentially explosive political force, although there is no evidence that rapid population growth is by itself the cause or even the major contributing factor in violence and aggression.

Consequences for Education

Because the numbers of children grow even more rapidly than the total population, the need for educating ever larger numbers inhibits the raising of enrollment ratios and improvement in the quality of education. High proportions of children reduce the amount out of any given educational budget that can be spent for the education of each child. Because each cohort, or age group, of the population is larger than its predecessor, it is difficult to recruit sufficient numbers of teachers from among the adult population.

Health, Welfare, and Child Development

The cost, adequacy, and nature of health and welfare services are affected by rapid population growth in much the same way as are those of educational services. In the individual family, maternal death and illness are increased by high fertility, early and frequent pregnancies, and the necessity of caring for excessive numbers of children. The physical and mental development of children is often retarded in large families because of inadequate nutrition and the diseases associated with poverty, and because the children are deprived of sufficient adult contact. Poor and crowded housing in the urban slums of rapidly growing cities produces further illness and retardation.

Environmental Deterioration

Necessarily rapid increases in agricultural production, both of crops and livestock, in many areas increase erosion, soil and water deterioration, and destruction of wildlife and natural areas. Pollution, caused by the indiscriminate use of pesticides, poisons people and domestic and wild animals.

Efforts to Solve the Problem

Over a billion births will have to be prevented during the next 30 years to bring down the world's population growth rate from the present 2 percent per year to an annual rate of 1 percent by the year 2000. The task may well be the most difficult mankind has ever faced, for it involves the most fundamental characteristic of all life—the need to reproduce itself. An unprecedented effort is demanded, yet success will depend on the private actions of hundreds of millions of individual couples.

Until very recently, few nations had explicit population-influencing policies. Like the movement of a glacier, population changes were barely perceptible from year to year and yet were inexorable in character, seemingly beyond the range of government policy. Only within the last few years, when the vastly accelerated rates of population growth have become apparent to all, have governments recognized the needs and the possibility of actions to protect their people from the consequences of their own fertility and to effect reductions in fertility. Population policies are thus a new and untested area for politicians and administrators, who have neither tradition nor public consensus to guide them.

Nevertheless, many governments of developing countries are now adopting policies aimed at reducing birth rates and high rates of population growth. During the 1960's fifteen governments in Asia, nine in Africa, and fifteen in Latin America and the Caribbean area began to undertake fertility control programs, or to give support to unofficial programs in the absence of explicit formulation of government policy. The total population of the countries which have or support family planning programs is nearly 1,900 million, 80 percent of the population of the less developed world. Several of the rich countries, many intergovernmental agencies, and private foundations are providing financial help and expert advice for these fertility control programs.

This book is designed to stimulate planners and decision-makers of developed and developing nations to examine the consequences of rapid population growth for their own social and economic policies and patterns of action. That governments can and will take action we assume as the natural course of human affairs. Our goal is to encourage a thoughtful examination of the consequences of rapid population growth and their implications for public policy.

II

*The Demographic Setting**

World population at the beginning of 1970 was over 3.5 billion. Less than two human generations ago, in 1930, it was 2 billion. About eleven generations ago, 1650—the onset of the modern era—it was only half a billion. In little more than one human generation hence, in the year 2000, world population could easily reach 7 billion and possibly greatly exceed this number. Growth rates have quickened: the world population increased from half a billion in 1650 to 1 billion in 1825, to 2 billion in 1930, and to 3 billion in 1960. If present rates continue, there will be 4 billion human beings by 1975. The acceleration is emphasized by calling attention to the ever shorter period required to double human numbers—175 years between 1650 and 1825, 105 years between 1825 and 1930, and 45 years between 1930 and 1975.

The public has become more and more aware of the dramatic rise in the rate of world population growth during the three centuries of the modern era. Rapid growth has been one of three related population phenomena generating acute public concern. The other two are the increasing concentration of the world's people on a relatively small proportion of the earth's surface—a phenomenon better known as urbanization and metropolitanization—and the growing diversity of the peoples who share the same geographic area and, increasingly, the same life space and the same economic, social, and political systems.

These three population developments are of relatively recent origin, spanning no more than about three of the perhaps forty thousand centuries that man or a close relative has resided on this planet. Only during the course of the present century have these three interrelated developments combined to generate world, national, and local crises, and to force intensified attention to population problems.

During the first three centuries of the modern era, from 1650 to 1950, world population multiplied about fivefold, from 0.5 to 2.5 billion, but over

*See the following chapters in Vol. II of this study: Philip M. Hauser, "World Population: Retrospect and Prospect"; Nathan Keyfitz, "Changes of Birth and Death Rates and their Demographic Effects"; and Dudley Kirk, "A New Demographic Transition?"

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this time span the population of Europe (including the present Soviet Union) increased about sixfold, of Europe and European-occupied areas in the Western Hemisphere and Oceania combined, about eightfold. The population of northern America increased about 160-fold and that of Latin America about 14-fold.

During the same period the population of Asia increased by less than fourfold. (This contrasts with what must have been a much less rapid increase earlier. The *absolute* increases in Asia were very large.) In Africa, population merely doubled. It is clear that greatly accelerated growth occurred first among the nations that first experienced modernization—the combination of "revolutions," including the agricultural revolution, the commercial revolution, the industrial revolution, the science revolution, and the technological revolution. Explosive population growth, the "vital revolution"—a pace of growth without precedent in long-settled areas—did not approach present proportions among the two thirds of mankind in the developing nations in Asia, Latin America, and Africa until after World War I, and especially after World War II.

By the beginning of 1969 seven giant nations contained about three fifths of the world's peoples—some 2 billion. These nations are China with, perhaps, 730 million, India with 520 million, the Soviet Union with 240 million, the United States with 200 million, Pakistan with 130 million, Indonesia with 115 million, and Japan with 100 million.

Demographic Prospects

If present fertility rates persist and mortality trends continue, world population could reach 7.5 billion in the next 30 years. With reasonable allowance for reductions in fertility, world population could reach 7 billion by the century's end—perhaps the best estimate now possible on the assumption of no worldwide catastrophe such as a nuclear war. In the realm of the possible, also, is a world population considerably in excess of 7.5 billion if the growth rate continues to increase as it has done throughout this century.

In the shorter run, using the United Nations "high variant" population estimates giving a total of 7 billion by the turn of the century, world population will approximate 4 billion by 1975, 4.6 billion by 1980, 5 billion by 1985, and 5.7 billion by 1990. Almost certainly, the number will exceed 5.5 billion by 2000 because of the age composition of the present population. Potential parents are much more numerous than the present reproducing cohorts. These numbers underline the magnitudes of the problems that will face the world in the immediate future as population numbers continue to swell.

Between now and the century's end the developing nations are certain to experience higher growth rates than the economically advanced nations. By

the year 2000, the now-developing areas may well number some 5.4 billion persons; the economically advanced nations, some 1.6 billion. Thus, while the modernized nations will increase by some 600 million during the next 30 years, the developing nations could increase by about 3 billion or five times as much.

The accelerating growth in human numbers is shown by comparing observed and projected annual increases. Between 1900 and 1950 the population of the world grew by some 20 million persons per year. On the basis of the projections we have cited, it could increase by an average of 90 million per year during the second half of this century, and by as much as 150 million per year during the first 20 years of the 21st century.

Birth Rates and Death Rates

World population growth is entirely the result of natural increase—the excess of births over deaths. For any subdivision of the world, net migration—the difference between out- and in-migration—is also a factor.

The population "explosion" is, in general, the result of great declines in death rates along with continuing high birth rates. When death rates began to fall, as they did in European populations in the 18th and 19th centuries, and in non-European populations in the 20th, more and more children survived to adulthood and were themselves able to produce children.

Among Europeans and populations of European stock, death rates declined rather slowly, requiring many decades to fall from 30-35 per 1,000 to the 15-20 per 1,000 typical of most less developed countries today.

Populations of European stock and, more recently, Japan have largely completed what demographers call the "demographic transition." Birth rates have declined from highs of 30 to 40 or more births per 1,000 population to below 20 per 1,000. Since death rates in these populations have now declined to the level of 10 per 1,000, annual growth rates are 1 percent or less, compared with 2 to 3.5 percent in less developed countries.

The great reductions in mortality did not reach the two thirds of mankind in the developing nations in Asia, Latin America, and Africa until after World War II. In general, birth rates have remained high, with the result that these areas are experiencing higher rates of natural increase than ever characterized the developed countries of today. Latin America, the most rapidly growing continental region, at 3 percent per year, will double its population in about 23 years.

The Recent Decline in Mortality in Less Developed Countries

The average expected lifetime at birth (life expectancy) for the population of India in 1910 was about 22 years, probably not much different from what it had been during the previous 2,000 years. For the less developed countries

of Africa, Asia, and Latin America as a whole, life expectancy in the decade of the 1920's was probably less than 35 years, lower than it was in 1840 in western Europe, Canada, and the United States. An extremely rapid rise in life expectancy and a corresponding decline in death rates occurred during the first two decades after World War II, and is still continuing, though probably at a slower rate.

The reasons for this remarkable change are not entirely clear. One cause was certainly the widespread control and virtual elimination of malaria and some other insect-carried diseases. Others were the widespread use in rural areas of the less developed countries of vaccines and modern drugs, improved drinking water and sanitation, and better personal hygiene. All these public health measures, the products of modern technology, are relatively inexpensive and easy to use in the absence of much improvement in economic conditions. But improved nutrition resulting from greater abundance and better distribution of food supplies and some rise in per capita incomes have probably also been important factors in many regions. Famines on a widespread scale have been absent or infrequent owing to improved transportation and communications, and to greater concern for the welfare of the poor countries among food-surplus nations. There has been some speculation that human beings have developed more immunity to some microbial diseases or that the virulence of some microorganisms has declined. The period from the 14th to the 19th centuries has been called the "golden age of bacteria."

Recent Changes in Fertility in Some Less Developed Countries

In a few less developed countries there has been a significant decline in birth rates during the last 10 to 15 years. On the other hand, in at least some countries where birth rates are still high, these rates have apparently risen somewhat during recent years, probably because of greater survival and better health of mothers during their later reproductive years.

From 1960 to 1967 seven poor countries achieved declines in their birth rates of 20 to 35 percent: Taiwan, Hong Kong, Singapore, Mauritius, Barbados, Trinidad and Tobago, and Albania. Seven others showed declines of 12 to 19 percent: West Malaysia, Ceylon, Reunion, Jamaica, Puerto Rico, Chile, and Costa Rica. These rates of decline are much higher than those in the present developed countries during their period of demographic transition. Several other countries in Latin America seem to be approaching a point of fertility decline: Guiana, Venezuela, Panama, and Mexico.

In most of these countries there has been a substantial measure of economic development and, particularly, social change, including notable improvements in education, communication, social infrastructure, and life expectancy. Several of them have experienced a high per capita input of capital and technology from the rich countries. The evidence of these coun-

tries suggests that a certain "threshold" level of socioeconomic development may be a precondition for a sustained drop in birth rates. This threshold level differs rather substantially from region to region and from culture to culture, being lowest in the countries of Chinese culture on the eastern rim of Asia and much higher in Moslem cultures and the countries of Latin America.

Age Structure Patterns

Before the decline of mortality in western Europe the combination of high fertility and high mortality produced populations that tended to be relatively young, with an average age of about 25. Five or six children were born during the reproductive period of women, but of these only two or three survived to become adults. During the first stages of the demographic transition, as mortality–especially infant mortality–declined while fertility remained high, the average age of the population became lower and family size increased because larger proportions of children survived. Among the economically advanced nations, the presence of increased numbers of children probably contributed eventually to declines in the birth rate, especially in urban settings in which children tended increasingly to become an economic burden. Larger numbers of surviving children called for much more parental care, attention, and support, and also increased the need for community and national provisions for the young, including schools, health services, and recreation facilities.

As birth rates declined in what are now called the developed countries, the populations grew older and family size again became smaller. The median age of western populations rose to about 30, and the number of children ever born declined to two or three per family. The developing nations today, in contrast, still have predominantly young populations with growing family size because of increased child survival. Therefore, the burden of dependency is relatively high in these countries and increases in per capita income are retarded because the number of nonproducing consumers (both children and adults) is about as large as the number of workers.

Fertility, Mortality, and Changes in Family Size

As life expectancy goes up and death rates decline, the proportion of children less than 15 years old in the population increases, provided that the fertility rates remain constant, because fewer children die. For example, with six live births per woman, the percentage of children goes from 39 percent when life expectancy is 30 years to 45 percent with a life expectancy of 60 years, an increase of about 28 percent in the child/adult ratio. The average number of children under 15 in each family increases in the same proportion. However, the effect of changes in death rates on the proportion of children and on family size is much smaller than the effect of an equal change in birth

rates. The principal demographic effect of rapid population growth resulting from a high and nearly constant birth rate and a low death rate—as contrasted with a nearly stationary population having both a high birth rate and a high death rate—is that the number of families in each generation is very much larger than in the preceding generation. This situation has serious consequences for a rural society with a limited supply of arable land, because it means that the size of farms for each family greatly diminishes from one generation to the next.

Three Population Types in Less Developed Countries

We may divide the less developed countries at the present time into three groups on the basis of their population patterns: (1) countries with both high birth rates and high death rates; (2) countries with high birth rates and low death rates; and (3) countries with intermediate and declining birth rates and low death rates. The first group consists of those countries, most in Africa and some in Asia, in which per capita incomes are extremely low and the process of modernization has barely begun. Probably only a few hundred million people are in this group. Most of the less developed countries in Asia and Latin America, and some in Africa—in all containing nearly 2 billion people—are in the second group. The third consists of a few countries on the fringe of Asia and in Latin America, in several of which there has been a marked improvement in economic and social conditions during the last 2 decades.

In the high-birth-rate, high-death-rate countries the life expectancy is about equal to that of Sweden in 1800, but birth rates are about 50 percent higher and the rate of population growth several times as great as in Sweden 170 years ago. (See Table 1.) In Honduras and Taiwan, which are, respectively, examples of the second and third groups of countries, the death rates are lower than in Sweden in 1966, because of their very young population, even though their life expectancies are less than the Swedish. Birth rates are 2 to 3 times as high, and rates of population growth 4.5 to 6 times greater in Taiwan and Honduras than in Sweden today. There is about one adult for every child under 15 in all three groups of less developed countries, in contrast to nearly four adults per child in Sweden in 1966.

Possible Future Increase in Rates of Population Growth

In the coming years it is possible that population growth rates in developing areas will continue to increase, even after declines in fertility rates begin, for continued declines in mortality may more than offset declines in fertility for some time. World population growth rates will continue to increase if decreases in growth rates in economically advanced areas are more than offset

TABLE 1

Three Population Patterns in Less Developed Countries
Compared with Sweden in 1800 and 1966

	High Birth Rates High Death Rates Average, 22 African Countries	High Birth Rates Low Death Rates, Honduras, 1966	Intermediate Birth Rates Low Death Rates, Taiwan, 1966	Sweden	
				1800	1966
Average population, millions	4.5	2.36	12.79	2.35	7.81
Birth rate/1,000	47.8	44.2	32.5	31	15.8
Death rate/1,000	26.1	8.7	5.5	26	10
Rate of increase/1,000	21.7	35.5	27	5	5.8
Doubling time, years	32	20	26	140	120
Life expectancy, years	37.1	60	64	38	74
Percent less than 15 years old	42.9	51	43.5	33	21
Density, persons per hectare	0.13	0.12	3.56	0.05	0.17

Sources: *United Nations Demographic Yearbook, 1966*. New York, 1969; Nathan Keyfitz, "Changes in Birth and Death Rates and Their Demographic Effects," Annex in Vol. 2 of this study.

by acceleration in the less developed areas. Furthermore, the advanced countries that experienced a postwar baby boom are likely to undergo a rise in birth rate during the coming years as an echo-effect of the first boom, and their population growth rates may, therefore, also increase.

Density and Developing Nations

Density as such is not an indicator of overpopulation. The density of population per unit of total land area in most less developed countries of Asia is less than the density in western Europe and Japan, whereas the density in the large countries of Africa and Latin America is about the same as that in such "empty" countries as the United States and the Soviet Union. Except for Taiwan and Egypt, which are exceptionally crowded, the density on cultivated land in all less developed countries is about the same as in western Europe. Most of the countries of Africa and Latin America contain large areas of arable but uncultivated land, but in Asia most land that could be cultivated has already been put under the plow. Modern high-yielding agricultural technology and fertility limitation must be introduced and expanded in these Asian countries if diets are to be improved or even if all people are to be fed in the future. (See Table 2.)

Urbanization

From 45 percent to 90 percent of the populations of the poor countries live in rural areas, but the rate of growth of cities in these countries exceeds their overall rate of population growth. For example, between 1950 and 1960, in twenty-four countries with per capita incomes of less than $250 per year, cities of more than 100,000 inhabitants grew 60 percent more rapidly than the total population. The average rate of growth of these large cities was over 4 percent per year; they were doubling in population every 17 years. The excess growth of cities was due to migration from the countryside, in part as a result of the diminishing size of farms and the increasing difficulties in making a living in rural areas. Although living conditions for many migrants in the cities are appallingly bad, they are probably better, from several points of view, than in the villages.

Desired and Actual Numbers of Children

Sample surveys of both urban and rural people in less developed countries show that a high proportion of couples having four or more living children do not want any more. The best current data strongly suggest that, on the average, the number of live births exceeds by one or two children the number

TABLE 2

Population Densities in Certain Developed and Less Developed Countries

	Population 1965	Total Area	Cultivated Area	Density on Total Area	Density on Cultivated Land
	Millions	Millions of Hectares		Persons/Hectare	
LESS DEVELOPED COUNTRIES					
People's Republic of China	730	956	145	0.7	5
India	483	304	162	1.6	3
Pakistan	115	95	29	1.2	4
Indonesia	105	149	18	0.7	5.8
Philippines	32	30	11	1.1	2.9
Thailand	31	51	10	0.6	3.1
Republic of China (Taiwan)	12	3.6	1	3.3	12
Ceylon	11	6.6	2	1.7	5.5
Ghana	8	24	5	0.3	1.6
Madagascar	6	59	3	0.1	2
Tanzania	11	94	9	0.1	1.2
United Arab Republic	30	100	3	0.3	10
Mexico	41	197	11	0.2	3.7
Brazil	81	851	19	0.1	4.3
Colombia	16	114	5	0.1	3.2
DEVELOPED COUNTRIES					
Soviet Union	234	2240	230	0.1	1
United States	195	936	185	0.2	1
Japan	98	37	6	2.7	16.3
France	49	55	21	0.9	2.2
West Germany	57	25	8	2.3	7.1
United Kingdom	54	24	7	2.2	7.7

Sources: (col. 1) *Population Reference Bureau Data Sheet*. Washington, D.C., December 1965; (col. 2) United Nations *Demographic Yearbook, 1965*. New York, 1966; (cols. 3, 5) United Nations Food and Agricultural Organization, *Production Yearbook*, Vol. 23, 1969. Rome, 1969. Col. 4 calculated from cols. 1 and 2.

desired. One reason is probably the high infant and child mortality in the less developed countries. Out of five or six live births, the probabilities are high that one or two children will die. For any individual family there is a large degree of uncertainty about the survival of their children. The excess children over the number desired can be thought of as a kind of insurance against this uncertainty. Moreover, though infant and child mortalities have been reduced in the last few years, people still remember the past high death rates for children. For example, in the Matlab region in East Pakistan, the average woman 45 years old has given birth to 7.6 children; 2.6, or 34 percent, of

these children have died. Today 21 percent die. Another important reason for the excess of live births over the number of desired children is undoubtedly the ineffectiveness, difficulty, and hardship of preventing births with the methods now available to the people of the poor countries. This is a powerful argument for family planning programs; but even if these programs were completely successful in eliminating unwanted births, the desired number of children in most less developed countries is so high that rapid population growth would still occur.

What Governments Are Doing

The governments of developing countries are now adopting population control policies at a rate and in a climate of world approval unimaginable even a few years ago. Among the nations that have officially decided to foster family planning are Ceylon, People's Republic of China, Republic of China (Taiwan), India, Indonesia, Iran, South Korea, Malaysia, Nepal, Pakistan, the Philippines, Singapore, Thailand, Turkey, Ghana, Kenya, Mauritius, Morocco, Tunisia, Egypt, Puerto Rico, Jamaica, Trinidad and Tobago, and Fiji. In many other countries at least the beginning of governmental interest and support is visible: for example, Hong Kong, Dahomey, Gambia, Nigeria, Barbados, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, El Salvador, Ecuador, Honduras, Nicaragua, Panama, and Venezuela.

The role of governments in reducing fertility is to exhort, inform, and provide; decisions and actions must be taken by individual couples acting in accordance with their perceived interests. Even so, the governmental task is large and difficult, requiring a high degree of organization, adequate financial and logistic support, great flexibility in meeting changing conditions, and continuing objective evaluation of results.

Only a small proportion of people in the less developed countries have even moderately good knowledge of modern methods of family planning; the poor and the uneducated need to learn what the well-to-do and the educated already know—that there are a number of safe, reliable, and simple ways of limiting one's family. Knowledge of contraceptive methods is much rarer than the desire not to have more children.

Another task of governments of developing countries is to find, to learn how to bring about, and to help individual families to recognize the changes in living conditions that lower the economic, social, and psychic benefits and increase the costs of having more than two or three children. Research is also needed to develop methods of fertility control that are easier to introduce

*Berelson, Bernard, "The Present State of Family Planning Programs," Paper presented at Conference on Technological Change and Population Growth at the California Institute of Technology, May 1970.

than the present oral contraceptives and mechanical devices. Much of this research can be done by the developed nations.

One by one, explicitly or implicitly, governments are actively assisting or deliberately allowing the extension of means and information to facilitate planning of family size by individual couples. For example, India and Pakistan have now deployed about one family planning worker for every 1,000 families. The U.S. Government has budgeted first $3 million, then $35 million, and ultimately $100 million in the last few years to contribute to the extension of family planning to those who need and want it in the less developed countries. Similarly, the U.S. Government budgeted $24.4 million, $55 million, and $80.6 million from 1967 to 1969 for family planning, research, and training in the United States.

Foundations and international nongovernmental organizations (including the Ford and Rockefeller Foundations, the Population Council, and the International Planned Parenthood Federation) have been particularly instrumental in catalyzing the development of national policies and programs. In many countries in which no explicit national population policies and no overt national population programs exist, there are nongovernmental associations demonstrating, in both the utilization and extension of family planning services, that family planning is respectable, beneficial, and desirable.

III

The Consequences of Rapid Population Growth

In thinking about the consequences of rapid population growth, it is useful to consider both the kinds of effects and the nature of the causes, whether these be the speed of growth itself, the underlying high birth rates, or population size and density. We are also concerned with the time spans over which the effects occur, and the scale; that is, whether we are dealing with a country or a region as a whole, or with the level of the family, village, community, or other small social unit.

In the discussion that follows we begin with the concern about adequacy of resources.

Resources*

Public concern over the adequacy of resources to meet the demands of a rapidly growing population advances and recedes; it never ceases, and for good reason. The arithmetical exercise that pits rising demand against a stock of resources that, in some ultimate sense, is physically finite though inadequately known, is both easy to perform and, for many, hard to resist. The dismal outcome is a foregone conclusion, provided the time horizon is sufficiently extended. Demand projections have an apparent persuasiveness, even when carried into the distant future, that is not matched by projections of supply which must be based on conservative assumptions if they are not to appear highly speculative. Projections of demand thus "swamp" projections of supply, and a crisis is predicted within easily specified time ranges.

The missing ingredient in this type of prognostication is the ability to measure man's capacity to manipulate the kind and volume of the resources he uses (including his ability to meet specific shortages of materials, the way in which he manages resource exploitation, and his control over his own numbers).

Providing for the required resources seems overwhelmingly difficult when we look into the future, and yet, looking backward, we learn that man seems

*See Joseph L. Fisher and Neal Potter, "The Effects of Population Growth on Resource Adequacy and Quality," in Vol. II of this study.

not to have failed, certainly not as disastrously as the forward look often presages. Specifically, mankind has not "run out" of any critical resources. Working through the market and the play of prices that operate on both demand and supply, costs of primary resources have not risen relative to other goods and services. In many instances they have fallen, and yet larger numbers of people now not only live longer but also enjoy higher standards of living, however measured, than were open to their forebears.

Management and Resources

Not surprisingly, the complexity of the resources issue has given rise to two basic schools of thought: One is inclined to take a very long view and doubts that technology can be relied upon to help extend resources at a pace to stay abreast of population growth; the other infers from the history of the past hundred years or so that science and technology can provide the basis for new discoveries (e.g., ore bodies, fuel deposits) and substitutes (e.g., petrochemicals, nuclear energy) to keep a step ahead of the "Malthusian trap." But not even the most ardent adherents of the second school argue that, without reduction and ultimate leveling off of the rate of population growth, the Malthusian proposition can be dismissed (short, that is, of a total recycling of all depletable materials).

Neither of the two approaches is as clear-cut as here stated. For example, leaving aside discoveries and substitution, much can be gained from more rational management of supplies of resources. The same piece of soil, managed differently, can be the basis for vastly differing rates of agricultural output. Identical deposits can be made to yield greatly varying supplies of fuel. Rational management is a prime variable in the sustainable yield of a given stand of timber. And so on.

Though less obvious, management is just as important in affecting the demand for resources. "Wastefulness" is usually identified with specific techniques or conditions associated with production or output, but its implications on the demand side, though less noted, are no less notable. Production subsidies that stimulate consumption beyond the point to which it would be carried if prices reflected true costs are a common example.

More recently, a subtle but specific case of subsidization has come to plague the high income countries particularly. "Environmental pollution" results, in one of its major manifestations, from the failure of prices to reflect the social costs that producers (and thus also consumers) are able to impose on society as a whole. Typically this pollution is in the form of liquid or gaseous effluents, but it can also take other forms with adverse impacts on the landscape, living things, or other facets of the environment. These social costs are paid in a context removed from their origins. When prices do not reflect them, partially or fully, certain products are in a very real sense priced

below their true costs, and demand for them is greater than it would be under conditions of full cost allocation.

Finally, people are neither mechanical robots nor fruit flies in their reproductive behavior. Parents the world over tend to behave over their lifetimes as if they were rational economic persons. Children entail costs and they provide satisfactions and returns. Parents tend to try to have an economically optimal number of children. In poor countries one reason for present high birth rates is that, in a very real sense, children are the poor man's capital.

The Role of Population and Income Growth in Resource Demand

Aggregate demand for resources is the product of per capita income and numbers of people. The relative roles of these two factors differ over time, between regions and countries, and in their impact on quantity and quality aspects of demands for different resources. In countries characterized by high income and low or moderate population growth, the effect of rising income in most situations outweighs that of rising numbers, often substantially, and the impact of high income is greater on quality than on quantity. That is to say, despite rising population, these nations have had only relatively transitory problems in procuring their material resources, by and large at constant cost and in some instances even at declining cost.

Rising incomes have triggered a vast expansion of durable goods mainly powered by mechanical energy, and nondurables designed to ease the burden of daily routines. Their joint effect has been not to create material scarcities, as was feared by some economists at the turn of the century and quite generally in the decade following World War II, but, as the ecologists had warned, to strain the capacity of the environment to absorb both the products that have served their purpose and the unintended by-products or residuals resulting from production, distribution, and consumption.

Income, rather than *number*, of consumers has been the more important factor in producing pollution. Analysis of historical data reveals that increases in aggregate energy consumption are caused to the extent of about two thirds by rising per capita consumption, i.e. income, and one third by rising population; and this appears to be as true in high income countries like the United States or the United Kingdom as in India or other low income countries. Especially striking is electricity generation, which is an important source of air pollution. In the past 30 years or so, 10 percent, at most, of the growth of electricity consumption can be attributed to population increase.

Human numbers as such have been a potent factor in aggravating the problem of maintaining privacy, or simply elbow room, which for a growing share of the population is harder to find. But even here, income is a factor. Rising per capita income, compounded by increased leisure time and more

rapid transportation facilities, has spread congestion from the city—where it is always present but where larger and larger parts of the population elect to live—to the nonurban landscape and most notably to recreation areas such as parks and beaches.

The situation so far has been quite different in less developed countries, where food claims half and more of a family's expenditure (surveys in India put it at 60 to 70 percent) and the elasticity of the demand for food is high. Because of the low levels of income in developing countries, even relatively rapid increases in per capita income have not in the aggregate put much pressure on nonfood resources. Food is a nonpostponable necessity of life for which there is no substitute, and because it absorbs such a large share of family income, it has always been the most critical resource problem.

At the same time, the rising demand for more and better food, which comes from both increased numbers and rising income, has pressed hard against land and water resources. To the extent that food becomes more widely available, expenditure patterns will change. Rising income will have increasing impact, and attention will shift from adequacy of food, land, and water to other resources, and unless the developing nations take extraordinary care, pollution will accompany these changes.

The Resource Future

From a worldwide view, divergent resource utilization and population trends suggest that, to the end of the century and probably beyond, there is sufficient promise in technology to assure the availability of resources, especially when technology is assisted by management to minimize wastefulness and maximize efficiency. Even for the short run, however, the confidence about resource adequacy in high income countries cannot hold for the poorer ones. Given the grossly unequal geographic distribution of many resources, optimism would be justified only if each country were endowed with enough nonresource-based earning capacity to obtain by trade what it cannot obtain by production. Adequate data on which to make such assessments are not available, and it is impossible to judge whether the resource position of each country will be analogous to that of the world as a whole. The fragmentary or episodic evidence that exists leads one to believe that the answer is negative. After all, although trade fills the gap in resource endowment, each country needs something to trade. That "something" is in many instances not readily apparent.

To illustrate, Fisher and Potter (see Volume II of this report) speculate on the magnitude of energy consumption by the end of the century. By assuming a continuing rising 10-year trend (1955-65), noncommunist Asia's energy consumption could reach 10 billion tons of coal-equivalent by the year 2000. At that level the area would enjoy a per capita consumption about 10 percent

above the level prevailing in western Europe in 1965. But this coal-equivalent of energy is about five times the aggregate consumption of North America in 1965, which was associated with a GNP of almost $750 billion. Assuming a pretty close correlation between GNP and energy consumption, the 10 billion tons of coal would be indicative of a GNP ranging between $3,500 and $4,000 billion. In 1965, the GNP of noncommunist Asia was $230 billion; thus the annual growth rate between 1965 and 2000 would have to be between 8 and 9 percent to make such a projection of energy consumption believable—a wholly unlikely event.

World energy resources could, in all likelihood, meet even this doubtful level of demand, but the prospective costs stagger the imagination. In financial terms, 1965 energy consumption was equivalent to almost $4 billion for the Asian area. For the hypothetical projection in 2000, the bill would be more nearly $100 billion—implying a demand for foreign exchange that can be produced only by exports and tourism. Thus, a reassuring global, physical outlook about resources (as Fisher and Potter caution) requires one to pay scant attention to geographic differences and the ability to pay.

In speculating about resource adequacy one can, on the other hand, easily be led to a much more pessimistic view than circumstances suggest. Exceedingly pessimistic projections can be, and have been, made by compounding projected world population with current per capita resource use in developed countries. Whereas this may serve to highlight the outer limits of conditions that could some day prevail, it is well to keep in mind that (a) such a development would occur only in association with levels of per capita income now prevailing in high income countries but which, as indicated above, are unlikely to be reached for a great many decades; and (b) there is little reason to believe that the mix of materials in these countries will in any way parallel that prevailing in the developed countries. On the contrary, it is quite likely, for example, that developing countries will skip the "coal and steel age" and take off into the chemical, and later into the nuclear, age at much earlier stages of their development than they would if they approximated the historical sequences of the developed countries.

The probability is small that the less developed countries will be in any way carbon copies, in their materials usage, of western Europe or North America. From this view, assessing the capacity of any specific country or area to obtain needed resources may yield in time quite different and perhaps more encouraging results. By implication, such considerations also put in a different light the often-voiced complaint that the high income countries, most prominently the United States, account for only a small share of the world's population but consume a major share of annual raw materials production. Apart from the fact that such consumption represents, in foreign trade, a major source of income for the exporting countries, it is quite possi-

ble that many resources will lose significance in the future, particularly as changes in relative prices influence the impetus toward substitution. Finally, there is every reason to believe that the final third of the 20th century will witness a great improvement in recycling of waste and thus depress the demand for new material, as well as open to question the conventional supply-demand resource balances.

Resources and Trade

The effects of rapid population growth on postwar world trade have been substantial and, on the whole, adverse to the developing countries. Among these effects have been steady erosion of exportable surpluses (i.e., surpluses in a market sense, not surpluses over amounts that would be required to provide satisfactory levels of living for everybody regardless of ability to pay) and the transformation of many less developed countries from large net exporters to large net importers, especially of food.

This transformation was due primarily to the fact that rising demands for food were not matched by proportionate increases in production. It took place not because larger portions of domestic production went into improved consumption levels, but because rapidly rising numbers of people had to be supplied with basic requirements, with little improvement in per capita quantity or quality of production. Unhappily it also coincided with the emergence of competing—generally man-made—materials developed in the industrialized countries. There was a reduction in the size of export markets for such commodities as rubber, fats and oil, fibers, leather, etc.; and the potential for substitution has by no means been exhausted.

The last few years, however, have opened up a different prospect. Recent advances in the agricultural performance of several less developed countries, briefly mentioned earlier, are altogether likely—perhaps by the mid-1970's—to produce commercial surpluses of food, especially grains. The Philippines is the first country to move into this situation. Pakistan hopes to join soon, as do others. To the extent that they do, the immediate effect—though dampened by the outlays for fertilizer, other chemicals, machinery, etc. required to achieve the new levels of output—can relieve the hitherto adverse trade and foreign exchange situations of those countries if donor-nation aid policies and competition are favorable.

The volume of future grain exports will depend upon the extent to which governments will want, or be able, to favor exports over domestic consumption of either grain or animal products. This policy involves not only efforts to supplement the purchasing power of the poor but also an account of the effect of increasing urbanization on food demand. The expected effect of urbanization is increased demand on the organized food market, and eventu-

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ally on the whole economy, through rising incomes. None of these contingencies, however, can obscure the principal new fact that additional food supplies are increasing the options.

Whether the aspirations of the newly emerging exporters will run into heavy competition in world markets, given the large unexploited production potential of traditional exporters from developed countries, is another unanswerable question.

Economic Consequences*

Public and professional attention to the economic consequences of population change tends to cluster about two poles of emphasis. One, crisis oriented, focuses on the possibility of systemwide disaster; famine, depletion of natural resources, and other ecological threats have been linked to population growth at least since the time of Malthus. The second pole of attention concentrates on the interrelationships between demographic and economic trends.

The word "crisis" is often attached to developments that are suddenly perceived but have long been in existence. Conversely, some economic-demographic trends are not called crises because they are unobtrusive or continuous; yet they may involve greater social burdens—or at least are more directly related to population—than do threats of "breakdown." For example, the social and economic costs from impaired maternal and child health resulting from high fertility may outweigh in welfare terms any probable threat of starvation or ecological collapse.

In analyzing the economic effects of population growth, it is important to distinguish between developed countries and much less developed countries. A minimum distinction in economic-geographic terms would separate most of Europe, the United States, Canada, Oceania, Japan, and a very few other countries from most of Latin America, Asia, and Africa, although a number of European-settled economies and subeconomies in these latter three regions may be classed as developed. With few exceptions, the developed nations are characterized by relatively long (50 years or more) histories of development, high incomes (with recent per capita gross national products, or GNP's, of about $1,000 as a crude but helpful dividing mark), and low fertility (birth rates of below 20 to 25 per 1,000 as an upper boundary).

The less developed regions, by contrast, have with few exceptions brief histories of development; current per capita incomes in the $100-$600 range (most being under $400 and those between $600 and $1,000 being more akin to newly developing areas than to developed areas in terms of basic economic structure and other indicators of modernization); and birth rates well above

*See the chapters in Vol. II of this study by Paul Demeny, Dudley Kirk, Harvey Leibenstein, T. Paul Schultz, and Theodore W. Schultz.

30 per 1,000 and commonly more than 40 per 1,000, which are more than double that of the developed regions.

In the less developed countries, and particularly in their predominant agrarian sectors, the main economic effects of rapid population growth are on supply; productive capabilities and capacities are more limited and population growth rates are very high. In the developed countries, with their moderately fluctuating demographic factors and high productive potential, the main effects of demographic changes are on demand; the main question usually is whether productive capacity will be utilized rather than whether it is large enough.

Food–The Crisis That Has Not Materialized

In the developed regions, the impact of population growth on food supply needs has been limited for many decades and promises to continue on a "non-crisis" path indefinitely into the future. In contrast to the developing regions, the main elements are moderate to low rates of population growth, high and rising domestic food production capacities, adequate and expanding capabilities for obtaining food imports as needed, and the fact that food consumption varies much less than proportionately with per capita income. Furthermore, rates of population change in developed countries have generally been declining for over a decade and long-term declines in the future seem more likely than increases.

In the less developed regions, on the other hand, the need for cautious or even ambiguous forecasts has been demonstrated vividly in recent years. Fears of massive famine or at least growing threats of spreading starvation, expressed by numerous competent observers until very recently, have been abruptly succeeded by a largely contrary, equally substantial, and informed consensus.

Given all due precautions, the record and the main overall prospects are noteworthy, even startling. Widespread famine that could reasonably be attributed to economic incapability has not been observed in any of the less developed regions for decades. Fear of famine reached a peak in the mid-1960's, largely as a result of crop failure in parts of Asia coupled with dwindling international food reserves. These fears have been allayed by the elimination of recent shortages and the prospects for a long-run sharp upward trend in output of food grains.

The change in expert opinion seems to have stemmed from the agricultural turnabout in India, where 2 years of severe droughts have been suddenly followed by what many informed observers regard as a confirmed "Green Revolution."

Previous declines in international food reserves have been superseded by very large and rapid build-up of surpluses, which in any event have always

been mainly a matter of policy in the high income areas and not of resource limitations as such. In the less developed countries, despite their very different basic resource position, agricultural policy has been reassessed as a prime mover of modernization and expanding output, which governments can manipulate at their option. Agricultural research and development have been encouraged and subsidized. Price incentives have helped to accelerate technical innovation and increased production by cultivators. Public policy has assigned higher priorities to providing irrigation water, new varieties of seed, and fertilizer. As a result, a trend toward food self-sufficiency is observed in a growing number of low income countries that previously were dependent on imports. In the opinion of many today, the world's food supply prospects have taken a radical turn for the better, at least for the next decade or two. Indeed, attention is now directed at problems of agricultural surplus. There are fears that export earnings will decrease as previously importing areas become more, or entirely, self-sufficient; that increased output in modern agrarian sectors will further depress the subsistence sectors by forcing down prices; and that increased landlessness and other "push" forces operating in the countryside will add to the already enormous social and economic costs of accommodating the flow of people to urban areas.

In short, fears of food supply disasters in the less developed countries seem less sustainable today than at perhaps any time in the last 25 years. Quite apart from the dramatic nature of the recent turnabout in the world food-population picture, the avoidance of any major disaster from economic causes would be noteworthy on other grounds. For one, it has been achieved in the face of unprecedentedly steep, and still rising, rates of population growth, involving rates and numbers today which are something like double or more those encountered in the less developed countries only 30 to 40 years ago. Although trends in food consumption per capita are too poorly documented to permit generalization for any su stantial part of the less developed countries, such data as there are on calorie and protein intake suggest that increases since the 1930's have not been uncommon, though with a number of important exceptions and with many more instances of shorter-run fluctuations or declines since the 1950's.

Whatever the actual facts in the documented cases and the many more undocumented ones, the trends in food consumption have clearly not impeded remarkable gains in longevity and disease control. (That they have been causes of such gains in any significant degree seems doubtful in most instances.) Death rates have fallen and life expectancy has risen spectacularly throughout nearly all Latin America and Asia and many parts of Africa—often at rates of change with no precedent in the recorded annals of the developed regions.

Despite the prevalence of high rural population density in many less developed countries, their trends in agricultural output have been remarkably

resistant to the adverse impacts of added numbers. For the less developed regions as a whole, growth rates of output between the mid-1950's and mid-1960's (i.e., before the Green Revolution) averaged between 2.5 and 3 percent per annum, a respectable level both by historical standards and the contemporary performance in developed regions. Nor has this been a recent or anomalous occurrence. Between the 1930's and 1950's, growth in food output within the less developed regions was again impressive by both historical and comparative guidelines, though, of course, it was accompanied by slower rates of population growth and less pressure on the agrarian sector.

Negative Effects of Rapid Population Growth. However, if we view the world food picture in terms of reciprocal effects of economic and demographic trends—granted that neither crisis nor disaster seems likely—a very different outlook emerges. Per capita food production in the less developed countries remained practically unchanged between the mid-1950's and mid-1960's in spite of substantial increases in total output. In the developed regions, on the other hand, per capita output increased significantly. Analysis of the actual output trends in the less developed countries shows that per capita production could have been approximately one sixth higher than was actually the case for 1965, had their population growth rates been those of the developed regions.

The less developed countries' output growth rates, despite their impressive level, came to only about two thirds or three fourths of the United Nations Food and Agricultural Organization Indicative World Plan objectives, and the entire amount of the shortfall could have been overcome by no more than a limited downtrend in fertility from traditional toward more modern levels—for example, from the present average of some 40 per 1,000 to 25 or 30 per 1,000.

Agricultural performance in the less developed countries continues to be highly subject to the vagaries of climate and weather. Sudden drops in food supply, which are usually accompanied by falling effective demand in the farm sector, reduced domestic saving, and worsened balance of payments, can spell the difference between substantial growth and stagnation in whole economies. New technology has partly countervailed the wind and weather, but the vulnerability of most less developed countries to such "exogenous" factors has not yet been significantly reduced, even where, as in India, the probability of longer-run agricultural progress seems substantial.

The main effects of agricultural transformation in the less developed countries could be relatively sudden spurts in output rather than a permanent upkink in trend from, for example, the recent 2 to 3 percent increase per year to a 4 to 5 percent annual increase persisting indefinitely into the future. Should this happen, continued population growth at current rates could, even if temporarily exceeded by output advances, again begin to dominate the

food-population balance—and negatively—in the longer run. Rapid population growth could threaten the adequacy of the food supply after a period, say, by 1980 or 1990.

At the least, there has now begun a period of perhaps 2 decades during which providing a country's minimum food requirements will not necessarily have the attributes of a daily crisis. But what is *possible* is by no means *assured*. Success with the new varieties depends on the ability of farmers to obtain irrigation water, fertilizers, pesticides, seeds, farm tools, and eventually machinery, transportation, storage, and new knowledge. To be able to make the necessary purchases, farmers will have to sell a fraction of their crops. This presupposes either considerable growth in domestic incomes, especially outside the agricultural sector—i.e., overall economic development—or the availability of export markets.

For food supplies in the long run, only the first alternative seems significant for the developing countries in general. A scramble among newly export-oriented producers to supply the needs of similarly situated and motivated countries is not likely to bring rewards to all. Nor, on the other hand, is encroachment upon the markets of the traditional grain exporters of the world, domestic or foreign, a likely prospect; and the markets for specialized agricultural exports—sugar, coffee, tea, rubber, bananas, cocoa, jute, and similar products—from the poor countries to the rich hold out few prospects of sufficient growth. Some may even decline, particularly when they are vulnerable to substitution. In summary, although the technology is at hand for a large increase in agricultural production and farmers have demonstrated their capacity for adopting it, there is a serious question whether the necessary economic conditions to sustain this trend may be attained or sustained, quite apart from troublesome social and political by-products the trend may create—in human resources, social stability, and effects on the environment.

Increased agricultural productivity eventually results in lower food prices, to the benefit of consumers. Over any decade, however, a *consumer surplus* necessarily becomes smaller per consumer when it is distributed among the rapidly increasing numbers of consumers produced by rapid population growth.

There are also questions concerning whether incomes will rise fast enough to absorb rapidly rising farm output, either directly or in the form of livestock products; whether the lower prices needed for market-clearing will tend to discourage the innovators; whether new government taxes on inputs or income will dampen enthusiasm; or whether sufficient funds will be available to continue the expansion of irrigated areas.

Some observers have conjectured that the capital investments for the economic development that must occur to sustain the agricultural transformation, both for needed inputs and markets, will require much larger capital inflows in the future. The Pearson Committee,* for example, advocates

*See *Partners in Development, Report of the Commission on International Development*, Chairman: Lester B. Pearson. New York: Praeger, 1969. pp. 143-148.

raising the rate of growth of economic development to 6 percent by 1975 and judges that this will require a flow of external resources equal to 1 percent of the GNP's of the rich countries—nearly a doubling of current aid. Although the 1 percent "target" may seem an arbitary notion chosen for its simplicity, the Pearson Committee reports that, according to studies now being conducted by a U.N. committee, the amounts thus transferred would not be inconsistent with what might be called "requirements" in the less developed countries. It is clear that continuation of recent rates of population growth is likely to shape internal needs in the poor countries in ways that will postpone desirable changes in trade, consumption, and investment patterns.

Agricultural transformations in the less developed countries not only affect food production and consumption but also will profoundly affect the distribution of overall income and assets. Land-tenure patterns, distributions of agrarian incomes and farm holdings by size, and rates of rural-urban migration are likely to be significantly modified. In all these respects, rapid population growth seems certain to increase the number of landless, subsistence, or disadvantaged peasantry and to raise the administrative burdens and social costs of absorbing urban arrivals. Conversely, a slower population growth could lessen the severity of these effects, once its cumulative influence on numbers began to take effect.

Economywide Effects of Rapid Population Growth

A macro view of demographic-economic interactions in the less developed countries, using overall income aggregates rather than food proper, leads to remarkably similar judgments. Unprecedented and still accelerating population growth has not prevented very rapid economic advance. Population growth, though not a negligible block to development and modernization, has also not been an overriding factor.

Increases in GNP during the 1950's and again in the 1960's were at rates which have just about matched the contemporary rates in the developed regions; they accelerated between the two decades, and they ranged well beyond the magnitudes recorded for the industrializing nations of the 19th century. Although much of the information about individual nations is subject to error, it would be surprising if the correct facts, were they known, would overturn the broad conclusions. By both comparative and historical standards, economic growth in less developed countries has been remarkably rapid, despite record population growth and its anticipated handicaps to development through reduced savings potentials, increased consumption needs, added imports and reduced supplies of foreign exchange, or lagging investment per unit of labor.

Among individual less developed countries, moreover, the relation between income (gross domestic product) and rates of population growth has been low during the 1950's and again in the 1960's. The statistical relations are, if anything, positive in each case.

Much the same patterns have held for the developed economies during the postwar decades. Here, however, one would expect population growth to have a positive impact on economic growth, since growth in the developed countries increases demand under conditions of high productive capacity.

To summarize, recent differential rates of change in productive performance have not been obviously related empirically to rates of population growth, in either the developed or less developed regions. Moreover, since the rates of output growth have been very similar in both regions over the last 20 years, the correlation is again essentially zero when the two kinds of economies are considered in combination.

What the data show is that population growth has not been sufficient either to force economic stagnation or to dominate empirical comparisons. However, when the specific causal interrelations involved are viewed directly, it appears clear that rapid population growth in the less developed countries has been a decided obstacle rather than an aid to economic growth and that the more rapid the rise in numbers, the greater the deterrent effects.

Urbanization. At subnational levels, such as individual urban or regional areas, the cumulative impacts from population change may work far more rapidly and have much greater relative importance. However, clear-cut demonstration of the welfare and policy implications of subnational population movements has been impeded in the past by other kinds of difficulties. No well-defined order of social priorities surrounds population settlement and distribution. The desirability of reduced versus constant fertility, or of sharper versus more gradual decline, would hardly seem cause for controversy in the less developed countries. However, the merits of slower as against speedier urbanization become murky when their counterpart phenomena of greater as opposed to lesser rural increase are also considered. Excessive urban build-up and agrarian overpopulation tend to be simultaneous phenomena in most less developed countries and no "lesser of two evils" theory has been developed to compare adequately, much less help choose between, the policy options they represent. Nor is there a more encompassing methodology at hand for dealing with entire systems of settlement, in which towns, villages, and secondary-size cities, in addition to rural areas and primary cities, would be evaluated as alternative residences. Some further consideration of this complex of questions is attempted in other sections of this volume.

Macro Gains from Lowered Fertility

The similar output expansion rates in the developed and less developed regions since about 1950, coupled with their very different population growth rates, have produced a persistently widening gap in their average per capita incomes. It is true, and should be emphasized, that the recent rates of per capita product growth in the less developed countries have not been small

when viewed historically. However, it is also clear that the continued high fertility in those countries has represented a costly lost opportunity for raising levels of living at rates consistent with remarkably effective productive performance. If the less developed regions could raise their current per capita income growth rates by one third, it would reduce their per capita income doubling time from somewhat over 25 years to 18 years. Under current circumstances this could be accomplished entirely through a fall of the average birth rate in the less developed regions from their roughly 40 per 1,000 level to 30 per 1,000, a 25 percent shift, which, in addition to its income effects, could have perhaps equally large family-welfare effects not captured by conventional income measures.

A larger decline in birth rates, down to the level of the developed regions—less than 20 per 1,000—would raise the stakes commensurately, again quite apart from food crises or other resources-disaster possibilities.

These comparative statistical judgments are, of course, essentially empirical and short-run. Whether they reflect stable long-run causal relations is at least highly problematic (though a number of specific case studies have suggested similar effects from commensurately large shifts in fertility). Much existing theory in this area—for example the classical "laws" of diminishing returns—has been irredeemably qualitative or deductive; practically none, including standard capital-output approaches, has been modeled sufficiently for statistical application and testing. Among the very limited numbers of statistically operational models that have been put forth, there are marked tendencies to utilize essentially the same—though untested—structural relations and to specify key parameters more nearly through crude empirical analogies with developed areas than by direct estimation. Such models probably overstate the influence of demographic factors affecting real savings and investment and understate such relatively "population independent" factors as exports and industrial development programs. Existing theory also understates the role of productive and distributive innovations and changing quality of work force, including the entrepreneurial sectors.

The magnitude of the macro gains to be expected in the low income countries from reduced fertility and slowing population growth over longer periods than a very few decades is probably impossible to determine reliably with present tools of analysis. What is needed are models that are predictively potent, yet can encompass the long lead times required before significant or even visible economic impacts can be traced to altered fertility trends. Assuming, for example, a sudden 25 percent decline in fertility, total personal consumption would not vary greatly in much less than 15 years (especially when the smaller consumption needs of children compared with those of adults are taken into account); educational and related collective consumption needs would stay largely unchanged for the better part of a decade, and neither labor-force size nor numbers of households would be substantially modified for something like 20 years.

Whether fertility in the less developed countries continues at current levels or declines drastically, the expected numbers in the 15 to 65 age group—the main labor-force ages—would be practically unchanged for 15 years and the rate of increase would vary only by about 5 percentage points over 20 years. For the main school-going ages of 5 to 15, a 5 percentage point effect after 10 years compares with one of well over 25 points in 20 years, with very similar orders of effect for total population, hence consumers, over these same time spans.

Persuasive explanatory or predictive models for dealing with demographic-economic interactions during or beyond such prolonged time intervals have not been devised.

In developed areas, fluctuations in fertility, rather than sustained levels or trends, have been predominant determinants of population growth rates during recent decades. The main impacts of such fluctuations often have been upon short-term aggregate demand rather than upon long-term supply. Here too, however, nondemographic factors—for example, employment policy, investment propensities, and foreign trade—have been important enough to command greater attention from policymakers and analysts. As in the less developed countries, the macro-economic effects of demographic trends typically require longer time intervals to acquire sufficient causal significance than do many of the main nondemographic variables.

These comments help explain why attention to "population problems" has been so largely of a "crisis" variety, in both the developed and less developed regions. A further and more serious possibility is that adverse effects of rapid population growth on economic factors are likely to be understated or discounted, as compared to nondemographic factors. Whether or not such impacts are fully discoverable, even in principle, their presumptive longer-run magnitudes and probabilities are nevertheless sufficiently established to accord them a high priority, once the relevant, and distinctive, time spans surrounding their operation are given their due weight.

Research over the past 2 decades on the relations between long-term trends in production and traditional factor inputs (land, labor, and capital) suggests that these factor inputs have accounted for surprisingly small parts of the observed growth in output. After allowances are made for changing amounts of labor and capital (including land), well over half of such increases in output in a number of countries have been identified as "residual," i.e., statistically unexplained. The inference is that other factors, in particular improvements in the quality of the labor force and general technological change, have been the foremost determinants of economic growth in modern industrial history.

This line of reasoning could have important implications for understanding demographic-economic interrelations. It would relegate to a much more secondary position the role of diminishing returns; it would not expect the

adverse impact from rapid growth (of both total population and the labor force) to work mainly through adverse shifts in factor proportions (ratios of capital and other nonlabor factors to labor inputs). Adverse effects of rapid population growth are more likely to arise from the impact of growth on the "residual" processes themselves—for example, through significantly reduced opportunities for raising levels of education, health, and other human-resource-developing programs.

Population Growth and Technology

Modern technology has increasingly been directed toward doing better or more cheaply or in a greater variety of ways those things that most people in the poorer countries cannot afford to do at all. A quick review of ten or twenty major innovations of the past 2 or 3 decades will confirm this seemingly sweeping generalization. Thus, until recently much new technology has had only limited relevance to the problems of less developed countries and, in a number of instances, has even affected them adversely. The "Green Revolution" is a recent and major departure.

This does not mean that technology cannot be or has not been imported from the richer countries. Indian steel mills, Brazilian petrochemical plants, and synthetic fertilizer plants around the globe are very important examples. The question is whether rapid population growth has impeded native development, importation, or adaptation of technology. Evidence on this point is scarce, perhaps because traditional analysis has focused on the availability of capital.

It has been argued that in the obverse situation—i.e., relatively scarce labor vis-à-vis land and capital—a pressure for technology develops to substitute for manpower, and that the emergence of technology in the early history of the United States was a response to such a situation. To the extent that this is true, it is a historical circumstance that will not coincide with the special requirements of the less developed countries, because the heavy emphasis on labor-saving in modern technology—including agriculture—does not meet the needs of countries with surplus labor or underemployment.

It can also be argued that there are a number of ways in which population growth has indirectly been a factor in retarding technology, though again evidence is not at hand. First, given the priority of food in the consumer budget, new technology has been most urgently needed in agriculture. The basic scientific principles that could generally be applied have long been available, but, to be successful, new agricultural technology requires the cooperation of a large, widely dispersed, unorganized mass of small producers who must be reached and reoriented. This requires time, programs, policies, organization, division of labor, and a market economy, all of which are scarce in a developing country.

In addition, natural environments differ sufficiently to make straightforward technological transfers in agriculture difficult, if not impossible. Finally, until a few years ago, governments in less developed countries showed little enthusiasm for promoting improvements and investing funds in agricultural productivity. Instead, in an effort to diversify and develop in the image of the industrialized countries, they gave preference to those segments of the economy that are most characteristic of modernity. But the inescapable primacy of agriculture, rooted in the need to feed rapidly growing populations, has been a brake on the progress of industrial technology, native or imported. Neglecting agriculture forced increasing diversion of resources to the importation of food. Both the failure of the governments of developing countries to establish technological priorities that conform to needs and the failure of developed countries to offer attractive alternatives prevented the expected gains of modern technology from materializing.

By holding down per capita income growth, population growth has constrained significant increases in the demand for nonagricultural goods and for services that could more readily have been supplied with the adoption of foreign technology. This consideration must be tempered, however, by the recognition that prevailing low per capita income levels themselves constitute a serious impediment. To rise from a national per capita income of, say, $100 per year to levels that can and do support a large number and variety of goods and services, such as those of the United States or western Europe, would—even at an annual per capita income growth rate of 3 percent—take almost 100 years.

A further adverse circumstance has been that nonagricultural, industrial raw materials (e.g., ores, fuels) from low income countries have been primarily destined for foreign markets. Exported prior to processing, they call mainly for unskilled labor. Low wage rates have kept the need for new technology from becoming a pressing matter. Moreover, these sectors of production in less developed countries have tended to be relatively insulated from the rest of their national economies, so that whatever new production technology develops does not easily spill over into the economy generally, a circumstance that is equally true for the plantation-type, export-oriented segments of agriculture. These "dual economies"—for example, in prewar Indonesia—have been extensively discussed in development literature.

Individuals and Households—Micro Effects

In both developed and less developed areas, demographic analysis has tended to focus on macro or social-scale implications and little on micro effects that occur at individual or household levels. The social costs in individual or household terms of rapid population growth tend to be chronic, even if severe; they are rarely the stuff of public crisis. However, family health and

child care—until now considered outside the economic market and nonmonetary in nature—have begun to receive closer attention.

Several workers have hypothesized that there are linkages between fertility levels and the productive (including entrepreneurial) capabilities of the labor force. Family size (or average number of children being cared for simultaneously over a considerable stretch of their pre-adult ages) has been proposed as being causally—and inversely—related to intelligence, child health and care, educational opportunities, and actual school performance. Such effects might be the outcome of two sets of causal factors: reduced "investment" in human resources when family income must be distributed over more children; and possible influences of larger family size as such, with income held constant. Most of the evidence available on the topic bears predominantly on the first class of effects, which, reduced to essentials, are really forms of intergenerational transmission of poverty, a long-familiar subject. Whether family size as such is significant for economic growth is still speculative at best and would probably require at least 10 to 20 years of intensive study to provide reasonably definitive answers, given the inherently longitudinal nature of the transmission processes in question.

However this may be, the processes may have much more significant, as well as visible, implications when the effects of family size are viewed directly in welfare terms, rather than as indirect productive inputs. The effects of rapid childbearing and shortened child spacing on infant nutrition and quality of child care, as well as on maternal health in low income countries, might turn out to be large. Such effects, along with many other "quality of life" indicators, are still largely "beyond GNP." However, even conservative allowance for their existence in benefit-cost terms could yield large income-equivalents. Indeed, given the substantial fraction of the total population annually involved directly with births in the high-fertility areas (perhaps one fifth or more, using a birth rate of 40 per 1,000 and assuming families of five or more including parents), the gains to individuals and families from fertility declines not only would tend to accrue more rapidly, but also might possibly be greater, than the corresponding macro-income effects that can be deduced using more conventional methods of measurement. Merely a one-child reduction in number of children ever born to each mother, if accompanied by commensurately extended intervals of child spacing, would affect the large majority of couples in the reproductive ages, and hence the majority of the total population, within as little as 5 to 10 years.

Socioeconomic Change and Fertility

Finally, a look at the reverse direction of interactions from social and economic change to fertility -reveals an even scantier base of knowledge. That fertility varies with socioeconomic status has long been documented in

statistical or group terms, but individual or family psychological bases for fertility have not been amenable to clear definition or successful analysis. Theories of family decision-making about desired numbers and spacing of births have all been deductive rather than empirically operational; for example, they are often developed by analogy with the pure economic theory of consumer durables.

At macro scales of observation, average fertility differences between highly developed and distinctly underdeveloped areas regarded as groups—for example, between nations with per capita incomes of over $1,000 and those under $400—are among the clearest and most stable comparative phenomena known to social scientists, but their finer statistical or dynamic structure has largely eluded analytic approaches. For example, correlations between fertility (birth rates or gross reproduction rates) and standard social and economic indicators have been close to zero as recently as 1960, looking at the less developed countries as a whole. However, a number of social and non-income economic indicators (such as communication and education) that have been examined recently suggest that significant inverse correlations may hold between these indicators and fertility within individual less developed regions such as Latin America, east Asia, and possibly others.

To summarize, rapid population growth has neither prevented overall economic growth nor brought about widespread famine. However, rapid population growth has resulted in a slow growth of per capita incomes, per capita food production, and standards of living while national economic growth rates are rapidly rising. Moreover, with current population growth rates, the present optimism about food production need not apply far into the future. An immediate and continuous decline in fertility would soon increase the welfare of individuals and households in all economies, and after 15 to 20 years could result in very substantial—and cumulatively rising—overall economic gains, particularly in the developing countries.

Political and Social Consequences*

High population density and rapid growth are blamed for many disturbing features of a changing world: urban violence, political instability, poverty, pollution, aggressive behavior, revolution, and hypernationalism. Nevertheless, empirical attempts to relate population growth to these political pathologies have been uniformly unsuccessful. There is no evidence that population growth decreases the level of political stability or increases the probability of conflict and violence and aggressive behavior.

*See Myron Weiner, "Political Demography: an Inquiry into the Political Consequences of Population Change," in Vol. II of this study.

One reason for what may be myths about population and political pathology is that population change is ordinarily associated with socioeconomic change, and change carries with it the high likelihood of at least some disruption. Some of the characteristic forms of behavior associated in the public mind with high population density may, in fact, be much more significantly related to the prevalence of poverty and discrimination.

Another reason is the neglect of the subject by serious scholars. In the presence of ignorance, the intellectual gap has been filled by opinion. For example, there is a feeling, quite unsupported by evidence, that people in densely populated countries are more prepared to behave in irrational ways and to seek remedies by violence for internal and external problems, because they value human life less. This feeling is supported sometimes by crude biological analogy and oversimplification of the complexities of the interdependency of demographic and social change.

Nevertheless, the beliefs concerning real or imagined political consequences of demographic behavior are of great political importance in themselves. Hearsay knowledge and ignorance are available to politicians, and, as in the case of *lebensraum*, can be used with great effect to convince people to adopt policies espoused by politicians for entirely other reasons. Clearly the only antidote to unverified hypotheses applied as guides to public policy or as sources of propaganda is to increase the sophistication of tested knowledge and to disseminate the results through public education.

In the following discussion of the political and social consequences of rapid population growth it is essential to bear in mind that the current concern about the negative consequences of this growth are set against the backdrop of powerful pressures to achieve new and higher levels of income, health, education, and well-being. These goals are given differing shades of emphasis depending on the society from which they spring, but it is safe to predict that in the developing countries of the world the great mass of people would happily embrace them all, sure in the knowledge that they need and want more of whatever they are. In an atmosphere of rising expectations political "solutions" have an ineluctable glamour.

Political Administration and Geographic Density

It is difficult to govern a large territory with a small and dispersed population. The high per capita costs of governing underpopulated regions increase the likelihood of conflict between central and subordinate government units when justice, health, and education remain locally based (as is usually the case) because of the difficult problems of transportation and communication associated with attempts by the central government to have continuing contact with the citizenry. This suggests that the larger the population, the more effective its government can be, because the per capita costs of govern-

ment are reduced. However, difficulties of another kind emerge as density increases. The larger the population, the greater the total cost of government, the less feasible the participation of the individual in the government—except for voting—and the greater the variety of interests seeking to influence the choice among options. With an increase in density, and in economic and social development, the organizational structure necessarily becomes more expensive and more elaborate and the people more subject to regulation, although the increased services government renders may compensate for this aspect.

No matter what the geographic density of people, it is clear that the strains upon the administrative resources of government are increased by the numbers of people that government must serve—just in terms of meeting the increasing demands for public services, such as public security, judicial processes, and legislation. Added to this are the specialized needs such as education, health, housing, transportation, communication, and whatever sort of regulatory devices seem needed to make the system operate with minimum friction. There is a high potential for conflict between central authority located in densely populated urban areas and local authority centered in rural, sparsely settled regions.

Differential Population Growth

Population growth is unlikely to be the same for all parts of a nation's population, partly because the mortality decline that creates growth is likely to be different from one sector of society to another, but principally because growth is ordinarily associated with socioeconomic changes that promote migration from one geographic and/or occupational sphere to another. Population redistribution has major political consequences: the breaking of old ties and forming of new ones on the part of the migrants, the dislocation costs for the sending and receiving populations as well as for the movers, a decline in the importance of systems of local political and social control. As development proceeds, populations tend to concentrate rather than disperse, and regional inequalities tend to become greater. One consequence of this process is that concentration in cities makes political organization more feasible.

Numbers and Political Power. Since numbers constitute an element in the relative political power of social groups, it follows that differential growth rates affect the distribution of political power within a society. This differential may be of less import for social classes than for ethnic groups, since the former are less visible and they gain and lose population by the process of social mobility associated with economic change. Conflicts between ethnic groups, on the other hand, are the counterpart within a nation of the kinds of conflicts between nations—conflicts that may be pursued by means of policies to gain demographic advantage. Ethnic groups are subpopulations with their

own patterns of natural increase. Differential size and growth, and the perception of this, are important political facts in all political systems, and perhaps particularly in democratically oriented systems. Population policy may be explicitly or implicitly employed to extend the dominance of one ethnic group over another, or to extend political control over an area not previously well populated, or more generally to influence public policy decisions in discriminatory ways. Intergroup relations may be exacerbated by the migration that generally accompanies population growth and economic development. If low-fertility groups advocate a general policy of low fertility, the policy may be perceived by the targets of the policy to be politically motivated!

From an international viewpoint, political or other social elites may see population growth as a measure of the strength of the nation. Military manpower is still regarded by some as an index of political power despite the lessons of current history. Thus one consequence of rapid population growth may be to stir dreams of political, military, or economic expansionism.

Implications of Changing Age Structure

An outstanding characteristic of a rapidly growing population is the tendency of different age groups to increase at different rates, with the younger ages expanding at a greater rate than the older ages. Conversely, a dampening of the growth rate affects the younger first and only later the older ages. There are three reasons for this pattern of increase by age: The largest decline in mortality is registered in the age group with the highest mortality level, the infants. Second, fertility changes are by definition modifications of the ratio of those aged 0 to those in the childbearing span. Finally, any change at younger ages is passed on with the passage of time to the reproductive ages and is reflected back through the process of reproduction.

A stationary population with high fertility and high mortality is a young population. With mortality decline and the resulting positive rate of growth, the population becomes younger—the more so the higher the rate of growth. When fertility declines, the population becomes older, reaching a maximum age when it becomes stationary at a low mortality level. Thus the typical sequence in a demographic transition is that a young population becomes even younger as a consequence of mortality decline, but then becomes older as a consequence of fertility decline.

This transformation of the age structure has many important ramifications for the body politic. Different age groups make different kinds of demands upon the state—for health services for children and mothers, for the various levels of public education, for employment opportunities for entrants into the labor force, for medical services and social security for the old. For example, with an increase in the number of school-age children, the govern-

95-852 O - 73 - 33

ment may be pressured to divert investment funds from industry to education. More generally, different parts of the social system, to the extent that their membership is age-defined, take on a different relative configuration as a consequence of population growth, and change the power balance of the society. As with the assessment of the consequences of other demographic changes, there are two levels of consideration: a change from a previous equilibrium situation is disburbing to the status quo, and a new stable pattern fails to emerge, so that continual adjustment rather than merely adjustment to a new equilibrium is required.

One outstanding consequence of the modification described is an increase in the dependency ratio as a consequence of an increase in the rate of growth. (The dependency ratio is the ratio of that part of the population unable to produce sufficiently to meet its own needs—say those under age 15 and over 65—to those in the intermediate ages.) Although this is clearly an increased burden on the society, it may be more bearable, because of three associated circumstances: first, the mortality decline that produces the change in the age distribution may be associated with morbidity decline and better health; because the producing population is healthier it is likely to be more productive. Second, the labor force, as the key subpopulation, will, like the general population, be younger. Finally—a more subtle point—it is possible that a decline in mortality, representing as it does a decrease in the role of chance and unpredictability in human affairs, may diminish the sense of fatalism, strengthen the feeling that it is feasible to control the environment and make meaningful long-range plans, promote a sense of future-orientation, and generally increase the prominence of secular rather than sacred attitudes.

One characteristic of a high-mortality society, in toto and within its constituent groups, is a strong correspondence between respect, authority, status, and power, on the one hand, and age, on the other—to some extent irrespective of performance. In a low-mortality, high-fertility society with great numbers of young people, the respect for age and the status quo may sharply decline and those organizations unprepared for this phenomenon may be subjected to great stress.

A final point concerns the possibility that a society will experience change because individual characteristics are a function of age. If, for example, it could be demonstrated that youth is linked with liberalism and age with conservatism, as is commonly believed, then a growing population, because of its more youthful age structure, would be a more liberal population. In apparent support of this proposition, many modern revolutionary movements have been associated with, and have utilized, an increase in the number of young adults. It is difficult to differentiate in this situation the consequences of youthfulness, per se, and the extent to which the brunt of the disadvantages of change falls predominantly on the young adults, or, from another perspective, the extent to which their concentration in urban centers makes them more available for political organization.

In point of fact, little can be said with confidence about the meaning of age for individual behavior in some abstract causal sense, because of two confounding circumstances: (a) Most research on the subject has unavoidably confused its significance as an identifier of the person's location in historical time. Do the political and social attitudes of those over age 70 show the consequence of an inevitable aging process, or are they the result of birth in the 19th century? (b) Behavior in an age is only partly a consequence of the characteristics the individual brings into the situation. Societies are organized to expect particular kinds of behavior, and are ordinarily successful in bringing performance into line with those expectations. One of the most likely accompaniments of a process of social and economic development is a modification of age norms.

Some Special Political Problems

Although the evidence is indeed thin, there is reason to speculate that rapid population growth contributes to (but does not create) certain unique types of politico-legal problems in less developed countries. For example, it appears reasonable to inquire about the size of the bureaucracy as a tool of administrative management in those countries in which there are pressures on the government caused by underemployment and unemployment.

Rapid population growth in rural areas can place remarkable strains on a legal system that presents real or perceived barriers to economic well-being; for example, the way land is held, its passage from generation to generation, and inheritance laws—all influence political decisions. Here the mix of political and economic consequences becomes blurred, and it is abundantly clear that not enough is known about the ways people react to and perceive these problems.

Finally, there is one clear political consequence of rapid population growth that has deliberately been excluded from this analysis: the sometimes exciting politics of fertility control—or family planning. This would be the subject of another entire volume, to say the least. It is possible to expect that education, information, and understanding of the consequences of rapid population growth will in the near future substantially decrease the volatility of this issue in most countries. Nonetheless, a different frame of reference and method of analysis would be required to make any definitive statements on this subject.

Society and the Family

The consequences of rapid population growth for the family depend heavily upon the associated changes that may be occurring in the society and the economy. For example, the arithmetic of child dependency would be very much altered if the society were to prescribe child education and proscribe child labor. Both developments would institutionalize the rights of

individuals, specifically the new generation, over the claims of family obligation, specifically to the older generation, and modify drastically the familism that has been so congenial to high fertility. Occupational opportunities outside the family farm would be another blow to the parent-child relationship, particularly since most such opportunities require migration of the child and allegiances to extra-familial organizations. Such changes would bring into question the pattern of traditional obligations of children to parents and place particular strain on the pivotal parental generation, which feel bound by the traditional demands of their parents without any compensating claims on their children.

In summary, the new demographic situation of mortality decline and rapid growth may represent a severe structural strain on relationships within the family. From one standpoint this situation may be viewed as a grave consequence of population growth; from another standpoint it may be regarded as a necessary step in transforming the social structure in order to make the new equilibrium one of low fertility and mortality. The obstacles to such a new equilibrium are considerable, because of likely opposition from those with a vested interest in the traditional structure—from some heads of governments, of armies, of religions, and of families, and from certain of the privileged and the property-owning. The outcome is obviously problematic, and will differ in detail from one culture to another, but it seems unlikely that the tide of social transformation that is sweeping the world can be more than postponed, whatever the current strength of tradition in any particular society.

Urbanization*

Urbanization is a product of a country's history, an irreversible process, and an inevitable concomitant of economic development. Two thousand years from now it is possible that our century will be recalled as that time in history when the population of the world was converted from primarily rural to primarily urban. Whereas in 1900 probably no more than a quarter of the world's population lived in urban settlements, by 2000 it is possible that 60 percent or more will be found in cities.

Recent Changes in Rural/Urban Population

The world figure, of course, does not reveal the great range to be found today. Table 3 provides relevant data on both the level of urbanization and the tempo of change in the period 1950-70. The developing regions ranged from a low of 10 percent urban (eastern Africa) to 53 percent (middle America and tropical South America). Stated generally, Africa south of the

*See Harley L. Browning, "Migrant Selectivity and the Growth of Large Cities in Developing Countries," in Vol. II of this study.

Sahara as of 1970 had so low a level of urbanization that its period of major transformation still lies ahead of it; at the other extreme, Latin America already has nearly half its population in urban places; and the great populations of Asia are intermediate. If we take 70 percent as the standard for developed regions (excluding Oceania), then by the end of this century only Latin America has a chance of reaching this level, but Asia and Africa may be close to 50 percent.

The same pattern is seen when the city (a place of 100,000 or over) population is examined. (See Table 3.) The relative positions of Latin America, Asia, and Africa are the same.

It is characteristic of the urbanization process that, the more it progresses, the more significant the part represented by large urban places among the total urban population. Even now the developing world contains many of the world's largest urban centers. Shanghai, São Paulo, Peking, Mexico City, Calcutta, and Rio de Janeiro all have estimated 1970 populations of over 7 million. By 2000 the world's largest urban agglomeration will very probably be in a now-developing country.

Table 3 does not show the rate of growth of the population as a whole nor the absolute sizes of urban populations. In Africa for the period 1950-1970 the percentage increase of the urban population was 177; for Latin America, 136; for Asia, 135. By contrast, in Europe the gain in urban percentage was only 39, even though the proportionate increase was slightly higher than for Africa. The explanation is, of course, that Africa had a much higher rate of total population growth. It is also due to the rate of change of the rural populations. In the developed regions of the world, from 1960 to 1970 the rural population declined in absolute terms; in a number of developing regions rural growth exceeded 2 percent per annum.

Since the rate of urbanization in a country can vary only between the known limits of 0 and 100 percent, in the life span of any given country the period of intense urbanization during which the society is transformed from a primarily rural to a primarily urban one occupies a comparatively short time span. The peculiar problems that are associated with rapid urbanization are not permanent features in the history of a society. It is this feature of urbanization that gives a sense of urgency to efforts to affect and to guide the urbanization process. Many developing countries are now in the most critical period, and others are now on the threshold, of this transformation.

The Tempo of Urbanization

Urbanization is always the product of a unique historical development. Once the pattern is laid down it is usually very difficult to alter. Once begun, urbanization goes forward; a country becomes progressively more urban. (The few exceptions to this rule involve the breakdown of the social order, as

TABLE 3

Levels and Change in the Urban Population by World Regions, 1950-1970

(percent)

World Region	Urban Population 1950	Urban Population 1970[a]	Rural/Urban Change 1950-70	Point Difference 1950-70	Population in Cities[b] 1970[a]	Rural Population per Annum Change 1960-70
DEVELOPING REGIONS						
Northern Africa	24.6	34.6	41	10.0	23.1	1.8
Western Africa	11.6	19.7	70	8.1	7.4	2.5
Eastern Africa	5.6	9.9	80	4.3	4.9	2.5
Middle and southern Africa	6.6	15.4	133	8.8	6.0	1.5
Middle America	39.2	53.0	35	13.8	20.1	2.3
Caribbean	35.2	42.5	21	7.3	20.7	1.7
Tropical South America	35.8	53.1	48	17.3	32.2	1.1
East Asia	12.1	25.3	109	13.2	16.1	.3
Southeast Asia	13.6	20.1	48	6.5	12.1	2.3
Southwest Asia	24.2	35.5	47	11.3	21.7	1.6
South Central Asia	15.2	17.8	17	2.6	9.8	2.2
Oceania	4.9	8.5	73	3.6	0.0	2.3
DEVELOPED REGIONS						
Northern America	63.8	75.1	18	11.3	57.4	–.6
Temperate South America	59.1	70.2	19	11.1	52.1	.3
Northern Europe	69.5	74.9	8	5.4	58.2	–.3
Western Europe	63.2	73.0	16	9.8	45.0	–.6
Eastern Europe	42.4	54.6	29	12.2	24.3	–.6
Southern Europe	41.5	50.7	22	9.2	29.6	–.1

[a]Estimated.
[b]100,000 or over.
Source: Kingsley Davis, *World Urbanization 1950-1970. Vol. 1: Basic Data for Cities, Countries, and Regions.* Population Monograph Series, No. 4. Berkeley: Institute of International Studies, 1969.

occurred in the ancient world.) The *tempo* of urbanization is, however, another matter; it varies from nation to nation and from one historical era to another. In general, countries that experienced their most intense period of urbanization in the 19th and early 20th centuries did so at a slower pace than are the developing countries now in their most dynamic phase of economic change. Another difference is, of course, the much more rapid overall population growth in the developing countries of today.

The Green Revolution and Urbanization. The speed of urbanization can be affected by many factors—wars, droughts, revolutions, depressions, booms, for example. It is often difficult to foresee over a decade or so what will influence this speed. The Green Revolution provides an illustration of this point. A transformation only recently begun, it has not spread to all developing countries, and its long-term success is still problematical; yet the Green Revolution promises to have a considerable impact upon the volume of rural-urban migration and therefore upon the rate of urbanization. Because it is based upon technological innovation, primarily the use of fertilizers, the Green Revolution favors the larger, more modern, and commercially oriented farms. This development, in conjunction with high rates of population increase in rural areas, can be expected to increase out-migration to urban areas. (Whether there will be mass migration of whole families and of all ages or simply an intensified exodus of the traditionally migration-prone group—the young adults—is not clear.)

In addition to its possible effect upon the size and composition of migration streams, the Green Revolution may affect future levels of urbanization, because the growing urban population can be provisioned better from internal sources. Higher agricultural productivity makes possible a higher level of urbanization.

Migration—the Major Mechanism of Urbanization

There are various combinations of fertility, mortality, and migration that can cause the rapid growth of urban populations. But it is most common in time and space that the major contributor is rural-urban migration.

To understand the urbanization process in a given region, it is important to know how many people are moving from one place to another. Data on migration streams are indispensable. It is equally important, however, to know *who* is migrating. Demographic characteristics (age, sex, marital status, etc.) and socioeconomic characteristics (education, occupation, etc.) are needed to understand the impact of migration on both communities of origin (rural and urban) and the urban communities of destination. All these factors affect incorporation of migrants into the urban milieu.

Return migration is another aspect of internal migration that is best understood by reference to community of origin and of destination. Reliable information on its magnitude is generally lacking, but it represents a significant proportion of all migrations. To an extent still not determined, return migration acts as a sorting mechanism, returning the less successful and least satisfied migrants back to their communities of origin.

The effect of in-migration on the further growth of urban population depends upon the reproductive behavior of the migrants, a complex phe-

nomenon as yet not well understood. Urban life with its constraints on housing and its system of rewarding the best-trained workers, should encourage small-family norms. Furthermore, the sex imbalance that characterizes much rural-urban migration, the greater knowledge and availability of contraceptives, and a greater incentive to use them tend to lower urban fertility. However, many of the migrants to urban areas are in the prime reproductive period, and there may be a relaxation of traditional constraints upon fertility.

The Absortion of Manpower into the Urban Labor Force

An inevitable consequence of rapid population growth is the virtually universal problem of absorbing natives and migrants into the labor force of cities. Many are never really "absorbed"; they are either unemployed or underemployed. At present there is very little evidence about how much variation in such categories is to be found among countries or among cities within a particular country. And, of course, the problem of absorption into the urban labor force can never be separated from conditions in rural areas from whence the migrants come.

It is pretty well established, however, that the structural transformation of the labor force is accomplished mainly by inter- rather than intra-generational changes: most men do not make radical changes within their work lives; instead, successive cohorts enter into higher-level occupations. Linked to this is the fact that the migrants' success in finding good (stable) jobs in the city is related to their age at arrival in the urban area. If they come at an early age, they are able to compete quite successfully with the natives. Consequently, special importance attaches to the age of entry of men moving into the urban labor market.

The Urban System

The concept of urbanization includes the system of cities—the forms of interdependence among the cities and their relations to hinterlands. Basically, systems of cities are described in terms of the urban hierarchy (the size distribution of cities within an area and the activities, or functions, associated with size) and the spatial arrangement of urban places in terms of their interrelationships with each other and their respective hinterlands.

The distribution of urban places by size in a country is independent of the level of urbanization. In some countries the urban population is concentrated in smaller cities; in others large cities dominate. Although there is no theory that can tell us what urban size distribution is most appropriate for various stages of economic development, several factors may be relevant.

Cities of different sizes generally perform different kinds of functions. The biggest cities in a country are "diversified"; they do not specialize in one kind

of activity, such as manufacturing or commerce. Some studies in advanced countries have tried to work out thresholds for various activities that appear only when cities attain a certain population. Unfortunately, there are few if any comparable studies of developing countries, but it seems certain that the results obtained in developed countries cannot automatically be applied to cities in developing countries. Almost certainly, the threshold for the appearance of many activities will be higher in contemporary developing countries.

An independent but related problem is determining economies and diseconomies of scale of different city sizes. Few would argue that there is a direct relationship between size and overall efficiency. At some point the diseconomies stemming from high land rents, traffic congestion, pollution, etc. will come to balance out or outweigh the advantages of population concentration and high division of labor. So little hard evidence is available on this point that little can be said other than to note that differences between developed and developing countries may be considerable.

These considerations come to a head in dealing with one prominent feature of the urban hierarchy, the position and role of the "primary" or first city of a country. Many developing countries are characterized by "high primacy"; the first city is many times larger than the secondary cities, and this demographic concentration reflects a high degree of concentration of governmental, economic, and cultural activities in one place in the country. There has been a tendency to condemn all cases of high primacy as being detrimental to economic development because they are "parasitic"–sucking out the best from the rest of the country and offering little in return.

However, conditions vary among countries. As an example, two countries may demonstrate equally high primacy; their first cities are five times the size of the second cities. In one country a review of the situation leads to a recommendation that the pattern be maintained, whereas in the other country the recommendation is to use all means to reduce it. Why the contrary policies? The first country is small in population (say 5 million) and compact in area. Assuming a good transportation network, the primary city is within a few hours of all populated parts of the country. The advantage of maintaining high primacy and moving, in effect, toward a city-state pattern is that it will permit the existence of at least one genuinely metropolitan center that can provide the range of goods and services that a modern country requires. One city of a million inhabitants may be better suited to the country's needs than five cities of 200,000 each. The other country has 50 million people and encompasses a large irregular area; therefore high primacy may handicap regional development. The one center cannot well serve such a large and dispersed population. And the primary city would attain so large a population that it would result in local diseconomies. In short, in primacy variation just as in other aspects of urbanization, no simple formula will suffice.

The Spatial Position of Cities and Regional Development. Regional planning is now accepted in principle in most developing societies. What is still not common, however, is an explicit recognition of the part that urbanization, and in particular the spatial location of urban places, could play in the elaboration of regional plans. Frequently, regions are defined–as, for example, river-basin authorities–without any reference either to the existing urban structure or to what it might become. The fact that cities are nodal points in the process of development is lost sight of. The role they play as "central places" in providing goods and services to an agricultural hinterland or to some lower level of urban places too often is neglected.

Within most developing countries there are areas that can be termed, from an urban standpoint, undeveloped (very low degree of urbanization and poor internal and external communiction); underdeveloped (substantial urbanization but not well articulated with the resources of the region); and overdeveloped (too much urban concentration–primary cities are the most striking example–in relation to resources such as water). Each of these situations requires its own set of directives. In particular, regions classified as undeveloped need careful attention, for it is here that the urban regional planner can do more than try to correct earlier mistakes. He can be instrumental in laying down an economically and socially viable network.

Costs and Benefits of Urbanization

At the beginning of this section we stated that urbanization is an inevitable concomitant of economic development. Yet much current discussion suggests that urban centers are a handicap to development, as shown by such terms as "overurbanization," "pathological urbanization," "parasitic cities." Whatever the merit of these criticisms, it should be remembered that both historically and currently a close relationship–that has been frequently demonstrated statistically–exists between indices of economic development and indices of urbanization. In the most general terms, productivity is greater in urban than in rural environments, because, briefly stated, the concentration of population brought about by urbanization permits a higher division of labor and reduces costs caused by the "friction of space."

There is great uncertainty about how to interpret studies that have tried to estimate the monetary cost of urbanization, i.e., how much money is needed to create a new job for a rural-urban migrant. The results usually show such high costs that it is concluded that it is better to reduce rural-urban migration drastically and to make efforts to keep prospective migrants in their rural communities of origin. It is difficult to argue with the arithmetic of these studies, but it can be asked if they are attuned to the reality of the situation. Any similar study in the period of intense urbanization of now developed countries would probably have yielded the same conclusions. Housing, for example, is and always has been a particularly troublesome

problem for societies experiencing rapid urbanization. It is doubtful that any country (possibly a Scandinavian one might be an exception) has been able to provide "satisfactory" housing, be it England in the 19th century, the United States at the turn of the century, or the Soviet Union following the Revolution. Some of the standards that are used in making the calculation of urban services have been unthinkingly imported from the developed countries of today. In Latin America, at least, there now seems to be a better appreciation of both the desire and ability of squatters and low income groups to improve their housing substantially through self-help measures.

Surely one reason why more attention seems to be drawn to the ills of the city is that they are much more visible and concentrated than they are in the country. Since they are linked to the amount of documentation or observation, reports of worse conditions in the cities are, in most cases, statistical artifacts.

For example, in developing countries, nearly all cities have a mass of unemployed and underemployed workers, but underutilization of manpower is a characteristic of both urban and rural sectors. Education and health services are often more available in urban areas.

Urbanization does have its own set of "costs," and the form that the urbanization pattern takes may not be well suited to the requirements of a country. However, major policy issues would still arise if urbanization were to be perfectly "proportioned" relative to economic development. Criticism of the degree of urbanization and the speed of the process is often misdirected; policy changes should be directed to the systems of cities within a region—the problems rooted in the urban size hierarchy and the spatial distribution of cities. The question is not whether urbanization is desirable—it is probably inevitable—but what form it should take.

Education and Population Growth*

There is considerable evidence from recent economic research that factors other than the amount of capital investment in the means of production or growth in the quantity of labor are of major importance in economic growth. Such growth requires much more than an accumulation of capital and an increase in the number of workers. New types of productive instruments have to be created, new occupations generated and learned in new contexts and locations, new types of risks have to assumed, and new social and economic relationships have to be forged.

Hence, the development factors include: (a) improvement in the quality of labor through education and other means of skill acquisition, as well as better health and welfare; (b) more favorable conditions for the introduction of

*See the chapters in Vol. II of this study by Gavin W. Jones, T. Paul Schultz, and Harvey Leibenstein.

innovation and technical change; (c) institutional changes leading to more effective organization and management at both governmental and private levels; and (d) a better environment for entrepreneurs. These factors are interrelated, and all depend to some extent on improvements in education.

Recent Educational Expansion

The number of children enrolled in the primary schools of the less developed countries rose 150 percent during the 15 years from 1950 to 1965, and the percentage of all children 6 to 12 years old who were in school rose from less than 40 percent to more than 60 percent. This marked increase in enrollment ratios (the fraction of the total age group who are in school) reflected in large measure the value placed on education by people of all classes and income groups in the developing countries.

Public pressure for more education probably came in part from increasing economic returns to skill and education as industrialization proceeded and in part from the widening disparity between the incomes of people who had some formal education and those who were illiterate. This disparity in turn came from the growing demand for skilled labor and the stagnation in demand for uneducated and unskilled workers, whose numbers were rapidly increasing because of high rates of population growth. Studies in four Latin American countries and in India show that the earnings of people with 5 to 6 years of schooling are double or triple those of persons who have spent less than 2 years in school. Persons with 11 years of education earn three to six times as much as functional illiterates.

Education of Children as a Form of Saving and Investment

Educational expansion means that many parents have been spending more to improve the education and skills of children even though this has become more difficult as the number of children in each family increased. These investments in the "quality" of children may be taking place at the expense of savings by households and corresponding capital investment in the physical means of production. Statistical analysis of a large number of less developed countries shows that the level of savings measured in terms of national income remains, over time, a relatively constant fraction of per capita incomes. This fraction does not increase as per capita incomes rise, but from country to country it shows a strong inverse correlation with child dependency ratios, that is, the proportion of children less than 15 years old to adults 15 to 65 years old.* (As we have seen, these dependency ratios depend directly on

*Nathaniel H. Leff, "Dependency Rates and Savings Rates," *Amer Econ R*, Vol. 59, No. 5, Dec. 1969. pp. 886-896.

birth rates and rates of population growth.) Total savings, including those invested in human capital through education and better nutrition and child care, though still low in absolute terms because of low per capita incomes, are considerably higher than monetary savings or investments in physical capital and may be rising more rapidly than per capita incomes.

Limitations on Expenditures for Education and Development

Allocating expenditures for education presents difficulties on the government, as well as the family, level. In low income countries public investments in education reduce the amount that can be spent by governments on capital investments for short-term increases in production. The proportion of the gross national product (GNP) that can be drained off in taxes by all levels of government is limited by the necessities of human survival. In India, for example, 60 to 90 percent of personal incomes must be used to meet the physiological needs of the people for calories, protein and other nutrients, clothing, and shelter. Governments also face other difficulties in raising sufficient direct and indirect taxes to provide the revenue that must be shared among education, health and welfare services, and capital expenditures for development. These difficulties arise from the low levels of exports and imports available for customs revenue and the frequently deteriorating terms of trade, the prevalence of family morality rather than public morality, and the lack of effective political and economic controls.

The situation of average households in low income countries is similar to that of governments. There are difficulties even when per capita incomes rise. The ratio of total savings to income cannot be increased very rapidly as per capita incomes grow, even if strong incentives exist, simply because the necessities of life require that a high proportion of income be used for food, clothing, and shelter. Increasing numbers of children in the average family keep this proportion high even when total family income rises. In economic terms, the "elasticity" of savings to rising incomes tends to be close to one. This means that consumption needs are not adequately met by present income and the bulk of any increase in per capita income will be used for increasing consumption rather than savings.

Educational Costs per Child in Developed and Less Developed Countries

On the average the developed countries with their high per capita incomes are able to spend both a greater percentage of national income and far greater amounts of money on public education than the poor countries. This contrast is widened by the large proportion of children in the developing countries, a result of high birth rates and low death rates. Therefore, even if the level of educational expenditure were the same, expenditures per child would be

much less than for low-fertility countries. For example, in 1965 the United Kingdom used 6 percent of its GNP for education, while Ghana used 5 percent. But the school-age population (5 to 19 years) was about 37 percent of the total population in Ghana and 22 percent in the United Kingdom. Thus Britain used nearly twice as large a percentage of its GNP per head of the school-age population as did Ghana. In absolute terms, the United Kingdom, with a GNP per capita of $1,800, spent about $500 per child for education, and Ghana, out of a total GNP per capita of $300, spent $15 per capita, or about $40 per child.

Education in the developing countries is further handicapped by the fact that educational costs per child in schools, in terms of per capita incomes, tend to be relatively high. The differential in incomes between educated and uneducated people is much larger than in the developed countries, and consequently the ratio of teachers' salaries (which constitute 60 to 80 percent of educational costs) to per capita incomes is commonly two or three times this ratio in developed countries.

Percent of National Income That Can Be Devoted to Education

The low incomes of developing countries are not in themselves a fixed barrier to the channeling of substantial proportions of income into education, provided governments give education a sufficiently high priority and are able to raise the necessary taxes. There is a wide variation among countries, but on the average they spend about 3.5 percent of national income on education. But there does not appear to be much correlation between per capita GNP and the percentage of national income devoted to education. At all levels of per capita GNP, this percentage varies widely, from 1.5 to 2 percent in Ethiopia, Pakistan, Nicaragua, and Portugal to about 6 percent in Kenya, Ivory Coast, Cuba, and Libya, and more than 8 percent in Zambia and Tunisia. Expenditures per child of school age have an even greater range, from less than $5 to more than $75.

Future Increases in Enrollment Ratios

In spite of the rapid expansion of education in the less developed countries, the absolute numbers of illiterates in these countries increased from 1950 to 1965 because of the population factor; the number of children in the primary age group rose more rapidly than the number being educated. Educational planners in Africa, Asia, and Latin America are aiming at a reversal of this situation in the future by raising enrollment ratios to above 90 percent as rapidly as possible.

Time Required to Raise Enrollment Ratios. In many countries such an increase in enrollment ratios would be extremely difficult and perhaps im-

possible to accomplish in less than 15 to 20 years. One reason is that accelerating rates of population growth and the low levels of secondary and higher education during the past 2 decades have resulted in a small proportion of potential teachers relative to the numbers of potential students. Teachers must be recruited from the smaller and more poorly educated cohorts of these past years, in some regions in the face of competition from industry and other sectors. Moreover, the increase in the percentage of the GNP used for education that is required to raise enrollment ratios can be attained only rather slowly in many countries, because it requires a reorganization of fiscal and tax procedures that may not be possible until the GNP becomes much larger than at present.

Savings in Enrollments Resulting from Reductions in Fertility. If the desired rise in enrollment ratios takes place over 20 years or more, the rate of growth of the school-age population will greatly affect the total numbers of children in school. This can be seen by analyzing the situation of a typical developing country in which the population of children 5 to 14 years old is increasing by 3 percent per year, and educational plans call for a rise in enrollment ratios from 40 percent at present to 95 percent after 20 years. If fertility remains constant over these 2 decades, the number of children in school at the end of the period will have increased by 338 percent. With a steady decline in fertility at a rate of 1.7 percent per year the increase will be 270 percent. If fertility declines by 3.3 percent per year for 15 years, the numbers of children in school will have increased only 206 percent. Thus the savings in enrollments resulting from sharply reduced fertility will be about 30 percent after 20 years. The effect after the first 10 years would be much smaller however—about 3 percent—because of the 5- to 6-year lag in the effect of a reduction in fertility rates on school-age population.

If the rise in enrollment ratios from 40 percent to 95 percent takes place over 30 years, the constant fertility projection gives a 517 percent rise in enrollment at the end of this period, whereas for a rapidly declining fertility the increase would be only 200 percent. A 51 percent saving in enrollment would be attained at the end of this period by the assumed rapid reduction in fertility. Fertility reduction would give a saving of only 3 percent at the end of the first 10 years, and 30 percent at the end of 20 years, just as in the previous case.

Effects of Declining Fertility on Costs of Education. The effects on future educational costs of declining fertility rates versus continuance of present high fertility are more difficult to visualize than the effect on future enrollments. A rise in enrollment ratios with continuing high fertility will require that an increasing percentage of GNP be devoted to education, even if GNP increases more rapidly than population. This results from the fact that the

costs of education per student increase about as rapidly as per capita incomes. Most of these costs represent teachers' salaries, and these rise as per capita incomes rise.

Moreover, if the school system is to be expanded and improved, the proportion of expenditures for buildings and equipment and the nonteacher component of recurrent costs must be raised. To create a more balanced system the ratio of students in secondary and higher education, relative to those in primary school, must be increased, even to ensure a sufficient number of primary teachers. In Africa and Asia, secondary education is six to fifteen times more expensive per student than primary education, and university education twenty-three to thirty-nine times more. Finally, improvement in the quality of education must be attained primarily through raising teacher qualifications, and this means both greater costs and a lengthening of the time for teacher education, and a rise in salaries more than proportional to the increase in per capita incomes, if education has to compete for personnel with industry and other sectors.

For a given increase of GNP, per capita incomes will be higher if fertility declines and population growth is slowed. Hence the cost of education per student will increase more than if fertility had remained constant. Consequently, the effect of a fertility decline on educational costs will be less than proportional to the reduction in the number of children to be educated. But calculations for a typical case–Pakistan–show that whether or not enrollment ratios and educational quality are improved, total educational costs would be significantly smaller if present fertility rates were rapidly lowered than if fertility were constant. This is basically due to the fact that the proportion of children to adults in the population would diminish. In 1985 the percent of GNP required if fertility remained high would exceed that required for rapidly declining fertility by 13.9 percent if enrollment ratios held constant, by 10.4 percent if enrollment ratios are raised, and by 9.4 percent if, in addition, pupil/teacher ratios are lowered. In 1995, the excess in the high-fertility case would be 38.5 percent, 29.9 percent, and 27.5 percent respectively. By 1995, the amount saved each year would be about 900 million dollars, more than four times the *total* expenditures for education in Pakistan in 1970.

High Rate of Economic Growth Required to Increase Enrollment Ratios. The calculation for Pakistan assumes a growth in GNP of 6 percent per year, or about 350 percent by 1995. Even with this very high rate of growth, more than 8 percent of national income would have to be devoted to education in order to accomplish the planned increase in enrollment ratios, unless there is a marked decline in fertility. Practically no country today allocates such a high percentage of resources to education. If the economy grows at a slower rate, the increase in enrollment ratios would probably be impossible to attain without a sharp reduction in fertility.

Urbanization and Education

Another consequence of high rates of population growth that affects education is the rapid urbanization that is occurring in most less developed countries because of migration of redundant workers and their families from the countryside. Both enrollment ratios and educational standards are usually higher in urban than in rural areas. Therefore, educational planners need to keep these differences in mind and to take into account the rates of urban migration both in planning the allocation of educational resources and in budgeting additional funds for raising enrollment ratios and improving educational quality.

Allocation of Educational Resources

Without greatly increased educational expenditures, the necessity of providing primary education for rapidly growing numbers of children inevitably diverts resources away from technical, vocational, and higher education, all of which are required in many countries to provide the skilled technical manpower essential for economic growth. One of the most difficult problems faced by educational planners and administrators is to strike an optimum balance between the two kinds of education, in the face of public pressures for expanding school enrollment ratios and for a broader geographic distribution of schools.

The Role of Education in Reducing Fertility

The quantity and quality of education affect fertility rates, and hence population growth, in several ways:

1. Education postpones the age of marriage. Educational opportunities for women, particularly secondary and vocational education, tend to raise the age of marriage. This is clearly seen in the Khanna District of the Punjab in northwestern India, where the age of marriage of women has risen from less than 17 to more than 20 during the past decade as education and employment in teaching, nursing, and other occupations have become available. This postponement of marriage is one of the contributing causes to the decline of the birth rate from 38 per 1,000 in 1957-59 to 32 per 1,000 in 1966-68.

2. Educated women have fewer children. Evidence from several countries shows that women with 7 or more years of schooling have fewer children and smaller families than women who have had little or no education. The reasons are complex and not entirely understood, but among them are probably the greater access to information and to communications media possessed by educated women; the alternatives to childbearing available to them in the form of jobs and opportunities for service; their increased role in family decision-making; their greater ability to provide adequate nutrition and better health for their children, with the result that they are faced with less uncer-

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tainty about their children's survival; and their realization that a small family will make it easier to provide education and social mobility for the children.

3. Educational costs to the parents lead to smaller desired family size. Even when the costs of teacher salaries and the capital and equipment costs of education are paid by the state, children in school are a considerable expense to their parents. Their material needs are greater and they are less able to contribute to family income. Hence parents perceive their interests are better served by having fewer children.

4. Economic and social development resulting from education tends toward a reduction in fertility. As we have pointed out, an increase in the quality and skills of the labor force, together with other individual and social characteristics related to education, are probably the most important elements in economic and social development. At the same time, there is evidence that a certain level, or rate, and character of development are necessary conditions for a marked decline in fertility under the present circumstances of less developed countries. Although both these propositions rest largely on statistical grounds and are difficult to quantify or state in any rigorous fashion, the empirical relationships seem clear. We may say with some conviction that an increase in the quantity, an improvement in the quality, and a raising of the average level of education in most developing countries would promote economic development and thus a slowing down of population growth.

Time Lags in Educational and Economic Development

Both high rates of population growth and the poverty that is synonymous with underdevelopment severely impede a rapid expansion of education. The time lags for interaction between population and economic change and educational improvement are long. A reduction in fertility would significantly improve educational prospects only after about 10 years; there is also a lag of about 10 years in the effects of education on economic development and on fertility. Neither the developed nor the less developed countries can afford to relax their efforts to bring about a reduction in fertility by all acceptable means or to take advantage of every opportunity for capital investment and institutional change that offers a possibility of speeding up the development process.

Consequences for Public Health and Health Services*

Public health technology applied on a mass scale in the developing countries has reduced death rates dramatically. Yet the level of personal health

*See the following chapters in Vol. II of this study: John Cassel, "Health Consequences of Population Density and Crowding"; Leslie Corsa, "Consequences of Popula-

services for the individual and the community varies widely and, in general, remains far below the levels of the more developed regions. National leaders and the public aspire to a level of health services that will reduce mortality still further and increase the health and well-being of the people. However, as with education and other public services, high fertility forces health ministries to run fast to stay in the same place—let alone improve services. Unlike other services, however, personal health services can have a direct effect upon population growth by reducing mortality and by providing family planning services.

Governmental health expenditures in most developing countries are between 0.3 and 2.5 percent of GNP, ranging from less than 30 cents to several dollars per person per year. In most developed countries these expenditures are between $13 and about $75 per person and the fraction of GNP is usually between 1 and 4 percent.

Population Growth and Personal Health Services

For the next 20 years at least, the demand for health services will outrun the supply—by any measure such as doctor/population ratios or number of hospital beds. Rapidly growing population combined with higher aspirations make this inevitable. A study of doctor manpower needs from 1955 to 1965 in thirty-one developing countries illustrates the problem of numbers.* To maintain the doctor/population ratios of 1955, 25 percent more doctors were needed because of rapid population growth. To increase the doctor/population ratio by 3.3 physicians per 100,000 people, from 17.9 to 21.1, 50 percent more doctors were needed by the end of the 10-year period. At zero population growth, only 18.5 percent more doctors would have been needed.

The age and geographical distribution of the population also affects the health services. In a high-fertility community the primary stress on health services will be the care of mothers and children. The problems of medical treatment for infants are substantially greater than the problems of treating young adults, and hence care of the young requires a higher doctor/population ratio than the care of people aged 15 to 45. The levels of personal health services are usually much higher in urban areas than in rural ones, both in terms of numbers of physicians per capita and in facilities.

In a high-fertility region many women have several pregnancies very early in their childbearing years and continue to bear children up to the time of menopause. Very young mothers, older mothers, mothers with closely spaced

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tion Growth for Health Services in Less Developed Countries—An Initial Appraisal"; and Abdel R. Omran, "Abortion in the Demographic Transition."

**World Health Statistics Report*, Vol. 21, No. 11, Geneva, 1969.

pregnancies—all high-parity mothers—face risks. Except in most favored socioeconomic groups, evidence suggests that a short interval between pregnancies depletes the mother's capacity to give her baby a good start. She also carries a higher risk for her own health and safety, especially if she has several pregnancies very early in her childbearing years. Fetal loss rate under such circumstances is higher, infant survival is lower, and malnutrition and some impairment of growth and development are found in the surviving children. Mothers not only suffer from illnesses associated with pregnancy and childbearing, but are more vulnerable to other health hazards of a more general nature. They bear the burden of caring for the children, often under unfavorable circumstances and frequently with fewer opportunities to avail themselves of any health services that may exist.

With closely spaced pregnancies, or high parity, or the combination thereof, there is also greater risk of early interruption of pregnancy and of prematurity. Where breast feeding is the only chance a child has to survive, early birth of another infant curtails the benefit from the mother's lactation and predisposes the child to Kwashiorkor or other types of malnutrition. Studies from the United States and the developing countries reveal the not surprising fact that, as family size increases, per capita spending for food goes down. As a result, corresponding diet inadequacies and nutritional deficits are common. Malnutrition in childhood is usually not clearly identified in mortality statistics, for it is largely reflected in deaths from dysentery, measles, pneumonia, etc. to which undernourished children have lessened resistance.

Abortion

Rapid population growth is usually paralleled by a lack of community experience in the use of contraceptives. The result is a large number of unwanted pregnancies, and, in many countries, frequent resort to induced abortion, particularly when the desirability and feasibility of limiting family size become recognized.

Abortion is widely considered both a social and a medical (or health service) problem. The sociocultural aspects of this problem are so varied and so intimately associated with the historical, legal, and religious patterns of individual countries that it is difficult to attempt any brief analysis of their complexity or to generalize about the way rapid population growth affects specific situations. It is possible, however, to assemble an impressive amount of evidence to give weight to two generalizations about abortion.

First, it appears that as traditional societies (no matter where) begin to make the transition from high to low fertility, the popularity of induced abortion as a method of fertility control rises markedly. It may even reach what has been termed epidemic proportions in some societies. Second, lawmaking bodies are becoming increasingly convinced by the argument that the

costs and dangers of illegal and unskilled abortions outweigh whatever other arguments are advanced in behalf of restrictive abortion laws. Arguments for community health and safety, and for women's personal freedom, are carrying the day in many communities, although the acceptance of legal abortion is far from uniform from one society to another or within societies.

To the health planner this situation presents some very serious questions, whether abortion is a legal or extra-legal means of fertility control. The prevalence of induced abortion beyond the law (particularly if in epidemic proportions) results in serious demands on health services for medical salvage procedures. In some hospitals in developing areas, from one fourth to one third of hospital maternity beds are used for postabortion cases. Yet low-cost legal abortion service cannot be provided unless there is a realistic resource base of facilities and trained personnel. This must be one element in the decision whether to provide legal abortion facilities as a major component of a fertility control program designed to contribute to social and economic development. Insofar as possible, the need for abortion should be minimized by providing women who wish to avoid pregnancy with easy access to contraceptive materials and information.

However, the complete elimination of abortion through the effective use of contraceptives is a distant and probably not attainable goal. In those societies in which the drive to limit family size is strong, the use of abortion tends to rise. It also tends to rise after the inception of effective and extensive contraception programs which help to inculcate a small-family norm. Nonetheless, experience in Japan and the USSR shows that the goal of eventually decreasing the rate of induced abortion by the use of other family planning methods is feasible when accompanied by intensive education and information programs.

Family Planning

The leaders of many developing countries see high natality levels as a handicap to overall development. During the next 20 years the trend toward expanded and intensified family planning programs will undoubtedly increase. In some societies, there are already attempts to achieve specific lower levels of population growth. In others the emphasis is more general—to improve maternal and child health and to alleviate the poverty that is associated with large families.

A national family planning program and government health services can interact in three ways:

(1) Particularly where a variety of fertility-control methods is offered, and especially if these include sterilization or abortion, the family planning program will often be a part of the personal health services provided by the government. The requirements for frontline workers are different for some

kinds of family planning programs than for other health services; the program management should have a high and semi-autonomous status; and the costs should be considered as new and additional to those for other services.

(2) If a drop in birth rates results from the family planning program, the need for personal health services will be less than it would be with continuing high fertility. For example, in a country in which the level of health services is being doubled, a 25 percent decline in average rate of population growth would produce a 15 percent saving in annual health expenditures at the end of 20 years, compared to the expenditures required if the rate of population growth is unchanged. The effect on maternal and child health services will be proportional to the decline in birth rates and will be felt as soon as a decline occurs.

(3) The family planning program may compete with the personal health services for scarce medical facilities and personnel, including physicians and trained nurses. Where family planning programs and health services are combined, there may also be a direct competition for funds; the budget for an effective family planning program is likely to be at least half the health services budget in those developing countries that spend less than 1 percent of GNP on health. Competition for personnel, facilities, and funds will arise as soon as the family planning program is initiated, before it has had an appreciable effect on fertility. The extra demand for physicians can be minimized by employing family planning workers who are not physicians, but who have been especially trained to carry out the necessary physical examinations and other activities required in the family planning program. This has been tried successfully in Pakistan. Modern techniques for induced abortion greatly reduce the time requirements for physicians to perform abortions, and the number of days spent in hospitals by abortion patients.

Health Consequences of Density and Crowding

The commonly held view that crowding and population density, per se, have deleterious effects on health probably derives largely from four empirical observations: (a) Traditionally the densely populated (i.e., urban) areas have *reported* higher death and morbidity rates. (b) Industrialization and urbanization have frequently been followed by dramatic increases in death rates attributable to infectious diseases. (c) Studies of military training camps have reported exceptionally high rates of virus diseases. (d) In some laboratory studies, deleterious health consequences are noted as the number of animals housed together is increased.

The orthodox explanation for these observations is that crowding increases infectious disease, mainly through a greater opportunity for the spread of infection. For example, outbreaks of upper respiratory infection among recruits in military training camps are explained as the result of the herding

together of large numbers of susceptible young men with a few infected individuals. But there is evidence that crowding also has other injurious health effects, which occur primarily during the period when the degree and extent of crowding is rapidly increasing. The effects appear to be much less serious when the rate of crowding is slow and the crowded population has sufficient time to become adapted to its environment.

Thus rapid population growth and its accompanying rapid urbanization are probably more injurious to health than actual population density. In many cases, however, it is difficult to isolate the effects of crowding, as such, from other conditions, such as poverty, poor nutrition, poor housing, and pollution, which formerly characterized all cities and still prevail in the rapidly growing cities of the poor countries, and in the "inner cities" of the United States.

Before the modern era, cities were often called "eaters of men"—their birth rates were usually lower than their death rates, and the population was maintained by continuing migration from the countryside. Even as late as 1950, urban death rates in the United States were slightly higher than rural ones. But by 1960 the situation had reversed, and in 1966 death rates in cities and towns were only half as high as those in rural areas. The incidence of infectious illness was much lower. This was at least partly the result of better sanitation and health facilities in the cities and suburban towns, relative to the rural areas, plus the fact that migration of younger people to the cities had left an older, more susceptible population behind in the countryside. Low morbidity and mortality also characterize crowded areas in other countries with high levels of health services and sanitation. For example, although Hong Kong and Holland have very high population densities, they are said to enjoy two of the highest levels of physical and mental health in the world. The levels of mortality and morbidity in the densely populated cities and towns of Great Britain are about the same as those in rural areas.

Both animal experiments and experience with human beings indicate that social stresses due to crowding produce physiological disturbances. In turn, these increase susceptibility to both infectious and noninfectious disease. The effects are most severe before individuals have had time to become adapted to the crowded conditions. In animals, physiological changes occur during the period when the size of the population in the same space, that is, the population density, is increasing. These changes include increased adrenal and other endocrine secretions and a higher level of activation of the central nervous system. It is believed that they result from increased social interactions which enhance emotional involvement and produce excessive sensory stimuli. Animals in subordinate positions within the group tend to respond in a far more extreme fashion than those at the top of the social hierarchy, both in the volume of endocrine secretions and in manifestations of disease and pathology. After the population has reached its maximum size and has become

adapted to the crowded conditions, the level of physical pathology drops to that of animals living in an uncrowded environment.

Some of the ameliorating effects of urban adaptation in human beings are suggested by the death rates from lung cancer in the United States. When controlled for the degree of cigarette smoking, these death rates are considerably higher in farm-born people who have migrated to cities than in life-long city dwellers. In a study of Appalachian mountaineers working in an urban factory, it was discovered that the first generation suffered from a high rate of illness and absenteeism; their sons did not.

In the rapidly growing cities of developing countries, the newcomers can be expected to be at the highest risk for another reason as well. A frequent accompaniment to urbanization is the atomization or destruction of the family and kinship groups that provide protection and emotional support to rural individuals. In the course of time, new types of groups develop in the cities to fulfill some of these functions, but it is often difficult, particularly for newcomers, to become effectively integrated into these groups. Individuals who are deprived of such meaningful group relationships, exposed to ambiguous and conflicting demands for which they have had no previous experiences, and frustrated at achieving their goals and aspirations, may be more likely to become victims of both infectious and noninfectious disease. Insofar as this effect exists, it is difficult to distinguish from the direct consequences of a rapid increase in the level of urban crowding.

It should be evident from this discussion that the magnitude and nature of the effects of crowding on human beings are highly uncertain. Much research is needed to clarify and quantify them.

Consequences for Children*

Many studies have been made of the effects of family size on the well-being of children within the family. In families with many children there are more malnutrition and illness of children than in small families; higher mortality rates among younger children; slower physical growth; and less intellectual development. Family size is not the only cause of these effects, but it is probably an important element in the interacting network of causes.

Excessive "crowding" of children, especially in a family with a young mother, seems to produce the same effects as excessive numbers of children. That is, the effects of short spacing between births are about the same as those of large numbers of children in the family.

*See Joe D. Wray, "Population Pressure on Families: Family Size and Child Spacing." in Vol. II of this study.

Infant and Child Mortality Related to Family Size, Birth Interval

In less developed countries infant and child mortality is much higher in large families than in small ones. For example, in eleven villages of the Indian Punjab during 1955-58, 206 out of 1,000 children died during the first year of life in families in which the mother had given birth to seven or more living children. In families of only two children, the infant mortality was 116 out of 1,000. The difference in mortality rates was even larger for children between 1 and 2 years of age—95 per 1,000 for the children in families of seven or more live births and 16 per 1,000 for two-child families. The same proportionate differences in mortality rates between children of small and large families are found in New York City, though the levels of mortality are very much lower.

The effects of short birth intervals on infant and child mortality in low income families are painfully illustrated by data from these Punjabi villages. In 1955-58, 310 out of 1,000 children, born less than a year after a preceding child, died during the first 2 years of life. This mortality rate was 55 percent greater than that of children born between 3 and 4 years after a previous birth, and more than twice as high as the mortality rate among children born after an interval of more than 4 years. The proportional differences in deaths during the second year of life between the three groups of children were about twice as large as the differences during the first year, though the mortality rates were considerably lower.

Family Size and Physical Development

In low income countries the high mortality rates among children in large families, and in families with close birth intervals, are in part due to malnutrition. The greater the sibling number, the greater the likelihood of malnutrition among poor families. Studies of preschool children in Colombia, for example, show that 52 percent of the children in families in which there were five or more preschool children were seriously malnourished, whereas only 34 percent of children in families with only one preschool child were malnourished. In Thailand, of the children whose next youngest sibling was born within 24 months, 70 percent were malnourished; of those in families without a younger sibling, only 37 percent.

Since growth is related to nutrition, it would be expected that the height and weight of children in large families would be smaller on the average than in small families. Even in high income countries the children of poor families are larger at any given age when the number of children in the family is small. For example, of 2,169 London day school students 11.25 years old, children from one-child families were about 3 percent taller and 17 to 18 percent heavier than children from families with five or more children.

The difference in physical growth between children of small and large families in Great Britain seems to affect mainly the poorer social classes. In the higher income classes boys in families with three or more children are taller at all ages than boys in small families; the reverse is true for girls. In the upper and lower manual working classes children in small families average 3-4 percent taller than those in large families at 7 and 11 years of age, and 1.4 to 2.8 percent taller at 15 years.

Effects on Intelligence and Educational Performance

Large numbers of children in the family diminish not only physical size but also linguistic skills, intelligence as measured by intelligence tests, and educational performance. These elements are to some extent interrelated; for example, heavier children mature earlier, and early maturers do better in school than late maturers. Experiments show that the apathy that is a major consequence of malnutrition is highly correlated with such psychological elements as lack of ambition, low self-discipline, low mental alertness, and inability to concentrate.

Both physical growth and the greater cultural nurture associated with small families appear to affect intelligence. In the sample of British day school children, intelligence increased with height and decreased with family size. The average verbal reasoning scores of children over 135 centimeters tall in families of one or two children were 5 to 7.5 percent higher than those of children of the same height in families of four or more children. The difference for children of the same age but less than 135 centimeters tall between large and small families averaged about 7 percent. Tall children from both large and small families scored about 6 percent higher than short children.

In studies of Scottish children the average I.Q. of only children was 113, that of children with five or more siblings was 91. In France, only children between the ages of 6 and 12 had an average mental age 1 to 2 years higher than children with eight or more siblings.

The differences in educational performance between children in small and large families are especially significant when the families are separated by social class. Data from the British National Survey of Health and Development show the performance of children in families of different size in educational tests at 8 and 11 years of age. In the upper manual working class, only children and those in two-child families scored about 11 percent higher than children in families of six and about 26 percent higher than children in families of seven or more children. The difference in the lower manual working classes between only children and children in large families was about 17 percent. In the upper middle class the difference in educational performance between children in large and small families was somewhat less than 9 percent. The difference in educational performance in all classes was slightly larger at 11 years than at 8.

A study in Scotland found the negative correlation between intelligence test scores and number of siblings held true for all social classes. In France, it was "clearly apparent" for children of farmers and manual workers, but "barely discernible" for children of the professional classes.

That the difference in children of large and small families persists in adult life is indicated by the average scores of army recruits on tests of different types in Great Britain. In the tests that measured general, verbal, and special mechanical intelligence, the recruits from small families scored 11 to 16 percent higher than those from families with five or more children, and the difference increased with increasing family size. On the other hand the difference in tests of physical ability was much smaller, only about 5 percent.

Possible Reasons for Greater Intelligence in Children of Small Families. It is likely that the ability to think abstractly, which underlies most kinds of human problem-solving, develops at an earlier age and to a greater degree if children learn the necessary verbal skills either from adults or from siblings considerably older than themselves. The smaller the family size, the easier it will be for children to develop such skills. These concepts receive support from psychological evidence that suggests that a young child's intelligence level can be raised by the environment in which he is brought up, including the cultural stimuli provided by the family, or by an urban setting. A high proportion of persons of outstanding intellectual achievement were either only children or came from families in which there was a large age gap between siblings.

Children in large families may suffer more maternal deprivation because of greater maternal illness and the stress of large numbers of children on the mother. The effects of extreme maternal deprivation are drastic and impressive. They result in lower linguistic skills and I.Q. scores and less success in later life. In one study, 50 percent of children deprived of maternal care were in a state of dazed stupor—apathetic, silent and sad, making no attempt to make contact with others, often suffering from insomnia, prone to infection, and dropping behind other children in development. The effect of extreme maternal deprivation is also well shown by comparing children brought up in institutions with those brought up in foster homes from early infancy. At the age of 3 years the I.Q.'s of the institutionalized children were 28 points lower than those of the children who had been cared for by foster parents.

An important question remains unanswered: Would the parents of large families among the poor have provided better for their children if they had had fewer of them, and would the children, in consequence, have achieved greater physical and intellectual development? Parents who *do* limit family size may be qualitatively different from those who do not. If the difference exists, it might result in both smaller numbers of children *and* healthier, more intelligent children in some families than in others. Alternatively, parents who

do not limit family size may have the same potential as those who do, but because they lack knowledge of, or access to, means of limiting family size, they are unable to do so, with the result that, *because* of excessive family size, their children are subject to more illness, receive less adequate nutrition, fail to grow well, and do not achieve their full potential for intellectual development.

These two alternatives are not mutually exclusive. The first may apply to some parents, the second to others. As we have seen, there is evidence that most parents in the less developed countries would like to control their family size. Many of them have more living children than they wanted to have. For those parents to whom the second alternative applies, the number of children they wanted might have been better cared for if the ones they did not want had not been born. If effective means were made available for all parents who want to control their family size to do so, a considerable proportion might use these means, and be better parents as a consequence.

Importance of Intelligence for Development. Intellectual capacity and the ability to manipulate abstractions that typify educated intelligence are important to economic development not only through the contribution of skilled specialists, such as engineers, lawyers, physicians, architects, and teachers, but also because of the broad category of managerial skills, from farm budgeting to central administration, that rest on intellectual capacity and the greater ability of intelligent workers to adapt to change and innovation.

Environment and the Quality of Life*

The assertion that rapid population growth adversely affects man's environment and the quality of life itself is rarely challenged. In developed areas we see the sky above the city veiled in thick smog, mining scars in mountainsides, dying lakes, rivers discolored from industrial effluents, billboards along highways, conversations interrupted by overpowering noises from passing jet planes, spots of scenic beauty marred by accumulations of empty containers and transistor radio chatter—an incomplete list that increases year after year; in less developed areas—wildlife displaced by artificial lakes, new irrigation canals spreading schistosomiasis to previously uninfected areas, land that should not be cultivated denuded and eroded, and native populations uprooted. Although each encounter with these environmental insults seems renewed evidence that the quality of life is indeed deteriorating, a number of questions must be asked about the role of population growth.

*See Joseph L. Fisher and Neal Potter, "The Effects of Population Growth on Resource Adequacy and Quality," in Vol. II of this study.

Population—Only One Variable

First, population growth is only one of several variables that affect the quality of life, however defined. Per capita income, the state of technology, the degree of concentration of human settlements, and the social and cultural diversity of the population are others. There is little doubt that, at least in the developed countries, sheer numbers are not nearly as important in causing pollution as are the high levels of consumption and the by-products of a highly developed and diversified technology. As pointed out in the section dealing with resources, the rise in energy consumption, for example, is due far more to increases in per capita income than to the growth of population, and many adverse effects can be attributed to technical factors that are not inevitable concomitants of energy production and consumption. Thus it would be a gross oversimplification to blame numbers of people alone for the set of problems confronting modern society. Moreover, it is impossible to isolate the effects of a single variable—like population—and picture life in a world adjusted for a different value of that variable unless we allow for inescapably associated changes in other variables. We may shed tears for the adversities or insults that confront us, especially as we compare them with our private visions of what might have been or could be, but we can never know what tears we might have shed had different combinations of factors given us a different world.

Preferences and Costs

For example, in the United States or western Europe the relatively low price of owning and operating private automobiles, closely associated with the rise of a mass market due to a large population and high incomes, has been a prime factor in making faraway places accessible, but the same automobiles in urban areas produce noxious gases that now befoul the air beyond the air's capacity to dilute or transport them. What is the net effect on the quality of life? Where is the trade-off between newly won mobility and clean air? Would the benefits of overcoming the adverse by-product, through new technology or through the modification of economic incentives, or both, be sufficiently attractive to stimulate manufacturers and users to pay the costs of developing and using products that do not befoul the air?

The point is that our reactions tend to be lopsided. In a way, the interest rate by which we discount the future also operates in looking back, but unevenly. The ugliness, dangers, and adversities of the past (called "the good old times") are heavily discounted in comparison with those of the present. Evaluating "trends" becomes a matter of impressions, difficult if not impossible to define in some objective fashion. Thus we are driven to look for more reliable indicators, such as conditions of the environment, natural and man-made, that we can measure, albeit with difficulty.

Yet a new difficulty arises. The question of what constitutes "the good life" is as old as man. What is new is that, for much of man's existence, it has been up to him, within limits, to elect to lead the good life. Today we question the quality of life, because it is perceived that deterioration is *imposed* upon us, since it operates on the environment in which we live.

To be sure, people do not *prefer* polluted rivers and air or *demand* jet noises or billboards as conditions of their continuing happiness. Indeed, these decisions do not ordinarily confront them. When they contract to buy a good or service, the price does not include the portion usually referred to as "social costs," i.e., costs that are imposed on society as a whole, or a given part of it, such as degradation of river water, of air, of a tract of landscape, etc. The market fails to let all who are affected participate. Participators include, beyond the buyer and the seller, others living and people yet unborn, whose lives will be affected by choices made now. The market reflects only a slice, albeit a large one, of the interests and costs involved. By excluding the social costs, it leaves them to be dealt with by different means, if at all. When they appear in a context that requires citizens to make a decision to forego other advantages and perhaps to pay directly, there is evidence that the associated price tag tends to lower the priority of the necessary remedial action. People will complain vigorously about the garbage that accumulates in public places, including those of scenic beauty, and will demand remedial action; but until they begin to perceive the ecological damage they suffer, they tend to resist more than nominal charges to alleviate the situation. Under these circumstances, the pocketbook is a fair indicator of these preferences, and that indicator throws doubt on the intensity with which people deplore various well-known blights—even in these times of deep concern about the environment. If social costs were included in the price of goods and services, those with high social costs would be less in demand and the shift in consumption patterns would lead to an enhancement of environment.

Some observers contend that preferences revealed in market behavior are not reliable guides to perception; instead, people act in certain ways because either (a) they have no option to act differently (that is, they go to crowded places because they do not have the means to go to those that are less crowded), or (b) they are uninformed or ignorant of ways to act that would lead them to treasure those aspects of life that are being appreciated by the "sensitive few," and give proper weight to societal problems. That is, were it not for market failure and insufficient information, people's preferences would reveal greater concern for quality.

Actually, little is known about preferences—how many prefer, say, rubbing shoulders as opposed to the number seeking solitude. Moreover, relevant research would have to take account of the fact that solitude, beauty, and similar intangibles are obtainable only at a cost, and a rising one. It is quite possible that a generation born and raised under conditions of crowding will not object to, and in fact may feel more comfortable in, crowds.

In developed countries the upper and middle income groups take material advantages for granted and are acutely conscious of the secondary effects these advantages produce. In the same societies the lower income groups are far more conscious of their material needs and tend to ignore side effects.

Measuring Changes in Quality of Life

Measuring changes in the quality of life should take account of both improvements and deteriorations. It should be a *weighted* average taking account of differences in preferences and reactions at specified levels of cost, and perhaps of intensities of such preferences (which surely would have a very real effect in a market situation).

It is one thing to judge that things are "bad" and quite another to judge that they are "worse." As has been suggested, there is little evidence on the second, especially as one looks further and further back and is careful to add up the pluses and minuses. There is, on the other hand, widening and justified attention to how "bad" matters are in terms of quality.

Partial answers can be obtained by considering deterioration of specific *aspects* of life. Although good measurements still are scarce, air pollution, water pollution, urban density, overcrowding of recreation areas, etc., as evidenced in recent years, suggest a worsening. To the best of our knowledge, these conditions have not as yet become irreversible (except for vanished species); that is, they are, at a cost, amenable to treatment by both new technology and changes in incentives and institutions. It is perhaps worth noting, however, that the one area probably least amenable to such treatment is deterioration in the "space-solitude-privacy" complex due to sheer rise in numbers of people (from the subway rush to the crowded recreation spot), a phenomenon to which there is as yet no promising approach. This statement is not contradicted by the likelihood that life in a metropolis can provide more social privacy than in a small town. There are a few well-developed devices for dealing with the "overload" of environmental stress caused by numbers and proximity. But the intrusions, especially those of a physical kind, become harder to ward off, notwithstanding adaptive behavior. And they surely are a factor in the quality of life.

Problems in Low Income Countries

Most of what has just been described applies more to high income than to low income countries, partly because living at the margin of subsistence in developing countries allows little to be finally disposed of or abandoned, i.e., the rate of recycling is high. Low income restricts both the magnitude and the variety of consumption, including consumption of energy in all its manifestations. The ills caused by poverty leave little room for concern about—or expenditures for—the environment in ways that now preoccupy many people in high income countries.

The kinds of environmental adversity that exist for the less developed countries result much more from rapid population growth combined with a *lack* of technology than from rising incomes and the *presence* of new technology. In agricultural areas, extension of cropping into rain-fed areas that are at best suitable only for grazing, and of grazing into areas that should not even be grazed—prevalent over much of the arid Middle East, for example—has led to extremely poor soil conditions, remediable in part by better management (e.g., controlled grazing) and new technology (scientific farming).

> Many of the savannah or semi-desert areas . . . are the worst abused land resources and the resulting erosion presents a major problem requiring not only technical solutions but legal and social regulation of grazing use, a very difficult task to enforce in nomadic or semi-nomadic communities.*

Rapidly rising population aggravates this kind of resource pressure, as well as the pressure caused by a lack of cheap fuel, leading in many places to near-total gathering as fuel wood of any shrublike vegetation that might otherwise begin to take hold.

Large new engineering structures, especially dams and lakes, although permitting increased production also bring their share of ecological problems. Extension of waterborne diseases, of undesirable plant life (e.g., water hyacinths that clog water courses, transpire water to the atmosphere, etc.) are well known. The need for heavy fertilization and application of pesticides that are inescapable accompaniments of a Green Revolution set in motion other disturbances, some of limited spatial extent, some having more far-reaching consequences. The very rapid spread of new technology designed to feed rising populations may have secondary effects on the environment to a degree and an extent yet unknown. Worldwide alertness to these dangers in developing countries may provide the time and the incentive for timely countermeasures.

Many of the primary environmental problems of the high income countries, correlated with a high degree of industrialization, mechanized transport, and high fuel use, have not yet appeared in poorer countries and are not likely to show up for some time, given low income levels. Here again, the experience of the richer countries could provide useful indicators of impending trouble.

Finally certain environmental phenomena could, if continued, threaten the survival of man. They derive basically from alterations in certain ecological systems, brought about by man-made interference. Modifications in the heat balance of the earth, ocean pollution, effects of radioactive waste emission in air or water, and genetic mutations triggered by chemicals are a few examples

*U.N. Food and Agriculture Organization, *Provisional Indicative World Plan for Agricultural Development*, Vol. 1., c69/4 Rome, August 1969. p. 45.

of such contingent threats. Unfortunately, these threats are poorly understood, and the degree to which they are mounting is uncertain since we generally lack reliable "baseline" data. Usually several variables are involved, working in different directions, and the degree of certainty with which we can predict both future trends and effects is small. Neither panic nor complacency is an appropriate response to this situation. These contingencies deserve the most careful investigation and monitoring, particularly in the developed countries today, because here even a very small probability of a very serious result should give rise to remedial action. Continued rapid population growth certainly will aggravate the effect of the unwisely applied technology or faulty economic incentives that have produced their emergence.

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IV

Population Policy

In a sense, all the policies of a nation that involve the welfare of the nation's people are population policies, but we are concerned here with policies related to changes in the quantity and quality of the population and its geographical distribution—in the numbers of human beings, their education and skills, and where and how they live relative to the space and resources available to each person.

As we have shown, the rate of change of population size, the levels of fertility and mortality, the distribution of people between urban and rural environments, and the rate of change of this distribution significantly interact with the social and economic welfare of people.

Two Kinds of Population-Related Policies: Population-Responsive and Population-Influencing

The governments of nearly all countries are committed to improving the welfare of their peoples, and population-related policies are one of the tools available to them for this purpose. Present rates of population growth are so high in most less developed countries that two kinds of policies are called for: *population-responsive policies* that will ameliorate or overcome the effects of unprecedented increases in population size and density, high birth rates, and high population growth rates; and *population-influencing policies* that will bring about a reduction in fertility and mortality and in growth rates, or will beneficially influence internal migration. Policies concerning employment, food supply, building of cities and towns, and resource development are in the first category; family planning programs and other policies to reduce fertility, public health and nutrition programs that lower mortality, and transportation and industrial planning to influence internal migration are in the second.

In much of the following discussion, we shall concentrate on *population-influencing policies* aimed at fertility reduction. We recognize that in several developing countries with large land areas, relatively sparse populations, and high fertility rates, government leaders may consider the need for a larger

population so pressing that they may be willing to forego the economic and social benefits of reducing fertility. We urge that in these nations the leaders (a) make themselves thoroughly aware of the demographic dynamics of their country and its interrelations with economic and social development, and give adequate attention to population growth and change in formulating development policies; and (b) examine closely the extent to which the substantial penalties to development that result from high fertility and rapid population growth and the benefits of reduced fertility and slower rates of growth may apply in the special circumstances of their country now and in the next 2 or 3 decades. Even a marked reduction in rates of population growth to the levels suggested later in this chapter will result in a doubling of population size in less than 50 years.

Asymmetries in Population Policy

There is a considerable asymmetry in the possible range of population policies for less developed countries. Policies to accelerate mortality declines are feasible and may be desirable, but on both humanitarian and political grounds no option exists either to increase mortality or to abandon efforts for further mortality reduction. Policies to reduce fertility are feasible and desirable, but policies to increase fertility significantly are not feasible because birth rates are already at a high level. Internal migration from the countryside to towns and cities is widespread in developing countries and may be subject to modification by policy, but except for certain special situations such as emigration from islands with limited resources, and emigration to alleviate political or ethnic conflicts, sustained international migration on a sufficiently large scale is neither politically feasible nor economically reasonable as a solution to population problems. Though greater freedom of international migration throughout the world is desirable from many points of view, it cannot now contribute very much to alleviating the effects of population growth, because the size of the earth's population is now increasing so rapidly.

The total number of people who emigrated from Europe and Asia to North and South America and Oceania during the 19th and early 20th centuries was about 60 million. This is less than 1 year's increase in the world's population at the present time. Transocean air and water transportation facilities have become very much greater during the past 50 years, and the aircraft and ships now exist to move this large number of people across the oceans each year. But even with enormous capital investments for education, job creation, housing, and other social infrastructures, it would probably be impossible for present sparsely populated countries to assimilate in their existing economies and societies the number of migrants required to offset significantly the problems of population growth in more crowded countries.

The needed teachers, managers, construction facilities, and institutions simply do not exist. Without such assimilation, population problems would in no way be ameliorated; they would simply be transferred geographically. Moreover, immigration is almost always differential; the young men, the able, and the venturesome would be the first to migrate, and those who were left behind in the home country would suffer grievously from their loss. A transfer of a much smaller amount of capital than that required for immigrant assimilation from the presently rich countries to the poor ones would probably go much further in bringing about economic and social development of the poor countries, and thereby in creating the conditions for a marked reduction in fertility and the rate of world population growth.

More than a thousand million hectares of arable but uncultivated land exist in North and South America and Africa. The longer the time during which world population continues to increase, the more likely it becomes that there will be no economic alternative to making very large capital investments to bring these areas under cultivation and to settle them with large numbers of people. But for the foreseeable future, food supplies can be increased to match human food needs much less expensively by raising yields and by multiple-cropping on presently cultivated land. Capital for agricultural development will be better spent and new technology more effectively applied on the farms of India and Pakistan, where almost all arable land is already cultivated, than in the sparsely settled parts of countries in which there are large areas of uncultivated arable land.

Population-Responsive Policies Called for by High Rates of Fertility and Population Growth

Rates of population growth in less developed countries are at least half, and in some cases almost equal, the rates of economic growth. Chiefly because of the high fertility of these countries, the ratios of children to adults are also very high when compared with these ratios in developed countries, and both the numbers of children and of young people entering the age of labor force participation are rapidly increasing. Because of these factors, planners and political leaders should take future population growth and change into account in all long-range planning. The following are a few examples.

Health and Educational Manpower

The numbers of teachers, physicians, and health workers who need to be trained must be equal to the sum of replacements for those who retire or die, plus additional personnel to keep up with the growing numbers of children in school and the numbers of children and adults requiring health services. If the

absolute number of functional illiterates (with less than 5 years of schooling) is not to increase, school enrollment ratios must rise, and, hence, the number of teachers to be trained must grow faster than the growth in population. This will also be true of physicians and health workers if the number of people for whom health services are unavailable is to be lowered. One task of policymakers in health and education is to balance the demands for quantitative increases due to population growth against the needs for improving the quality and level of education and the distribution, range, and effectiveness of health services.

Food and Agricultural Production

During the 1950's, development strategies in many less developed nations were concentrated on attempts at industrialization, in part based on the example of such recently developed countries as the Soviet Union. But these strategies did not reckon with the unexpected and unprecedentedly high rates of population growth which appeared after World War II and accelerated throughout the next 15 years. Though industrialization sometimes proceeded at a rapid pace, industrial employment usually increased more slowly, and the absolute number of people supported by the industrial sector lagged behind the growth of population, with the result that the number of people tied to the land in agriculture greatly increased. At the same time, population growth has brought about a vast increase in food requirements. Consequently, agriculture continues to be the base of the economy in most of the less developed world. In recent years, it has been widely recognized that much greater emphasis on agricultural improvement is essential for overall economic and social growth, and more balanced development strategies have been undertaken.

In Asia, where nearly all arable land is already farmed and most of the world's people live, a revolution in agricultural technology must occur if rapidly growing populations are to be fed even at present levels, let alone improved diets. For both economic and physiologic reasons, the rate of growth of food supplies should be substantially greater than the rate of population growth. The situation is summed up by the FAO.*

> Assuming a 2.6 percent annual increase in population there will be an extra one billion people in the developing countries by 1985. This alone would require an 80 percent increase in food supplies by that year compared with 1962, without any improvement in quantity or quality of individual diets. Success in raising income levels along the lines proposed in the "high variant" of the economic model, and consequent improvements in purchasing power, would increase demand for food by 142 percent

*U.N. Food and Agricultural Organization, *Indicative Plan for Agricultural Development, Main Conclusions and Policy Indications of Provisional Indicative World Plan.* Rome, August 1969. Vol. III, p. 57.

above the 1962 level, an average rate of increase of 3.9 percent per year. As against this the trend in food production over the decade 1956-66 for the developing countries taken as a whole was only 2.7 percent per year.

Agricultural revolution has already begun with the introduction of new high-yielding, fertilizer-responsive varieties of wheat, rice, and other cereals. If it is to continue, large expenditures for development of irrigation water, transportation, storage, food processing, and fertilizers must be made, including large amounts of imports requiring foreign currency. This will require overall economic development at a higher rate than has recently prevailed. These demands must be taken into account in planning resource allocations and priorities, and in raising capital funds.

The new agricultural technology is much better suited to some regions than to others. In India, irrigation development is easy to accomplish in the Gangetic plain of Uttar Pradesh and Bihar; it is difficult and expensive in most of the Deccan plateau, which covers central India. In East Pakistan, existing new cereal varieties cannot be grown and chemical fertilizers cannot be used, except for one crop during the dry season, in the 30 percent of the country that is flooded for 5 months each year. National farm prices will almost certainly fall because of greatly expanded production in the regions in which the new technology can be successfully applied. The farmers in the less favored regions may then be unable to sell their crops at prices sufficient to pay for the water, chemical fertilizers, and other inputs needed for high-productivity agriculture. They will be forced back on subsistence farming, but this will be insufficient to feed the growing populations of their own villages. Large numbers of poverty-stricken and unskilled countrymen will be driven out, either to cities and towns or to the more favored agricultural regions, where most of them will become landless laborers. The challenge to policy-makers, either to develop new agricultural technologies for nonirrigated land, or to provide employment and a new way of life for these people, is very great, especially because of the difficulties, already alluded to, of raising employment in the industrial sector as fast as the labor force grows.

In the regions in which the new agricultural technology can be successfully applied, capital and land give greater returns than labor, and, hence, it can be expected that the larger landowning farmers will gradually take over from the smaller ones and from tenants. This situation will increase still further the proportion of landless laborers and will aggravate inequities in income distribution. New land-tenure policies or other means to protect small farm-owners and tenants are called for. Problems of unemployment and underemployment may be increased as a result of unchecked agricultural mechanization, unless labor-intensive agriculture, combined with selective mechanization that increases the demand for labor, is strongly encouraged by the governments (e.g., tubewells to provide irrigation water and cultivating ma-

chinery for rapid seedbed preparation, which will facilitate growing an extra crop during the year).

Rapid population growth in rural areas in which the supply of arable land is limited results either in a fragmentation of farms from one generation to the next, or in an enforced migration of younger sons and their families to towns and cities. The average size of farms in the Punjab of West Pakistan has decreased by about 50 percent in one generation. The effects of farm fragmentation can be overcome by the formation of agricultural cooperatives among the small farmers, but experience in less developed countries shows that this usually occurs only under the impetus of strong government or outside encouragement.

Urbanization

In most less developed countries, cities are growing more rapidly than total populations, at least partly because stagnant rural economies have not been able to absorb rural population growth. In one carefully studied region of the Punjab in northwestern India, the rate of emigration during the 1950's equaled half the rate of natural increase of population. The situation has been considerably improved during the last few years by the rural prosperity resulting from the agricultural revolution described earlier. But in other regions, such as East Pakistan, where rural population densities average more than 1,200 people per square mile, the labor/land ratio cannot be much increased even with the multiple-cropping and increased crop yields brought about by the new technology. With present rates of population growth in the Province, room must be found in cities and towns during the next 20 years for some 15 million people. It may be impossible to accommodate these numbers in existing cities, and if so, new cities and towns and new industries must be created on a very large scale. Planners and policymakers will have hard choices to make in dividing scarce resources between investments to provide industrial and service jobs, and construction of housing, roads, water supply and sewage disposal systems, and other elements of urban infrastructure. Much experimental research needs to be done on lowering these costs of urban development. Other choices must be made between developing many small cities and towns of ten to fifty thousand inhabitants or large cities with millions of people. These choices should be based on a careful analysis of the full range of social and economic costs and benefits of each kind of urban place, the functions that can be filled by towns and those that must be reserved for cities, and the possibilities of influencing migrant behavior. One advantage of having many urban centers is that people may continue to live in the country and commute to a nearby city or town for employment. Thus, the small cities of Comilla in East Pakistan and Ludhiana in the Indian Punjab draw many villagers for daytime employment who return on bicycles and buses to their rural homes at night.

The lot of rural migrants to the cities of less developed countries would be greatly improved if they received more information about urban job opportunities and living conditions and training for city life before emigrating, and a more supportive reception when they first arrive in the city. Educational curricula, information media, and institutions need to be developed for this purpose.

Intergroup Conflicts

We have seen that in countries that do not have a homogenous population, rapid population growth creates or aggravates political and economic conflicts between racial, cultural, religious, and linguistic groups. The problems of ameliorating these conflicts have not been solved, and they represent a most serious threat to the existence of many states. In some cases, far-reaching measures such as mass migration or fragmentation of states into autonomous or semi-autonomous smaller units may be the only feasible policy options. But governments can do much by a more evenhanded treatment of different groups, providing not only equal but increased educational and employment opportunities and services for all, and by the political and legal devices that protect minorities without jeopardizing the basic interests of the majority.

Through better education and increased opportunities for social mobility, minority groups will learn that population quality is more important than numbers, and that improving quality is largely incompatible with rapidly increasing numbers. Experience shows that, over time, this will lead to lower birth rates and population growth and hence to a reduction in the levels of conflict.

Unemployment and Underemployment

The existence of large and rapidly growing supplies of cheap labor in many less developed countries tends to hold back the adoption of capital-intensive, labor-saving technology in industry, and thereby slows down increases in productivity and in standards of living.

Policies and programs to reduce the growth of the labor force by fertility control can have little effect during the next 15 years, because the young people who will be entering the labor force and seeking employment during that period are already born. For the near future, emphasis needs to be placed on (a) retaining as many workers as possible in agriculture by government policies that favor hand labor and those kinds of mechanization, such as tube wells, small tillers, and grain dryers, that raise the demand for labor by fostering multiple-cropping; (b) service occupations; and (c) relatively small-scale consumer-goods industries that in the aggregate can employ large numbers of workers. At the same time, efforts to increase productivity of these and other workers should be accelerated as rapidly as available resources allow, because only in this way can standards of living be raised. The produc-

tivity of labor in many less developed countries is now so low that industries based on it often cannot compete with similar industries in the advanced countries, even when wages are held at a subsistence level.

Population-Influencing Policies to Reduce Population Growth*

Control of population growth is one of the instruments available to governments to accomplish other objectives: economic growth and social development of the nation; improvement of the health and welfare of the people, both the living generation and generations to come; and conservation and improvement of the environment, both the natural environment and that created by man.

Progress in economic growth is usually stated in terms of annual rates of increase in the production of goods and services–the gross national product, or GNP–in the productivity of labor and capital, and in production or income per capita–the gross national product or the national income divided by the number of people in the nation. Growth in per capita income, in turn, can be thought of as an index, or surrogate, for rising levels of consumption of food and other goods and services, and improvements from year to year in education, communications, transportation, technology, housing, and other aspects of social development. Equally important as growth in per capita income is a narrowing of the gap between the rich and the poor, a reduction of poverty in absolute terms, and a greater perception, by the people, of equity in income distribution.

There are other kinds of policies that can be useful in attaining these objectives. Because all policies require the allocation of scarce human and physical resources, governments must necessarily strike a balance between them. In different countries this will depend, among other things, on the level of development, the balance between population and resources, political circumstances, and the administrative capacity of the government.

Some policies that affect population growth can also help to attain other social objectives in other ways. These multi-objective policies are desirable for several reasons, among which is the uncertain effectiveness, up to the present, of government policies designed to bring about demographic change. Profound changes in mortality and fertility have occurred in many countries in recent decades, but the quantitative effects of government policy on these changes are difficult to assess.

Policies to Reduce Mortality

Rapid declines in mortality have occurred in many less developed countries since World War II, resulting in a rapid acceleration of rates of population growth. But further declines can be expected to be modest in these

*See the chapters in Vol. II of this study by Arthur J. Dyck and J. Mayone Stycos.

countries, regardless of government policy, until a markedly higher level of overall economic development has been attained. In other countries in which mortality is still relatively high, governmental policies could bring about a sharp decline in future years. In these countries a drop in death rates may be an essential precondition for a marked reduction in fertility. Fertility and mortality policies are linked. The reduction of fertility is likely also to reduce both infant-child and maternal mortality, and a sufficient reduction of infant and child mortality may be necessary for reduced fertility.

Policies to Reduce Fertility

Time must pass before any development policy can accomplish its objectives. However, different government policies take different amounts of time before their impact is felt.

Time Horizon of Fertility Control Policies. The time spans over which governmental policies to reduce fertility can be expected to have a major influence on population size will generally be longer than the times required for other kinds of development policies (such as investments in natural resources, import substitution, increasing agricultural yields, electrification, and certain kinds of industrialization) to accomplish their objectives. However, the cumulative impact of a policy of fertility reduction, compared with maintenance of present fertility rates, can be very significant over periods of 10 to 20 years. Moreover, the difficulties of undertaking a policy of fertility reduction in a country with a high rate of population growth increase rapidly as time passes. Many more families will need to be involved to obtain a percentage reduction in fertility in future years equal to that which is now attainable with a smaller reproducing population.

In general, policies to reduce fertility have about the same time horizon as other policies designed to improve the quality of human resources, such as education, infant and child health, and welfare services. In drawing up the government budget, setting priorities, allocating administrative manpower, and deciding on alternative uses of resources, fertility policies should be considered in connection with other human resource policies.

Successful policies of fertility reduction will have a delayed impact on some aspects of social and economic development. For example, 5 to 6 years will elapse before a reduction in the number of births will be reflected in a smaller number of children entering primary schools. As we explained earlier, the size of the labor force will not be affected for about 15 years. The rate of family formation and the consequent needs for housing will begin to be lower at about the same time. The full impact on food needs will be delayed until the smaller numbers of children have reached later adolescence (15 to 19 years of age) and their nutritional needs are at a maximum.

On the other hand, a reduction in number of births will affect the need for health and welfare services for both children and mothers. The need for high-quality protein foods to save the lives and ensure the mental and physical development of children, and to protect the health of pregnant and lactating women, will decrease with the birth rate. And pressures for illegal and dangerous abortions will diminish with the successful dissemination of other means of fertility control.

At the micro-level of the family and the village, the effect of a prevented birth will be immediate in terms of smaller family size and a lower dependency burden, with the accompanying economic and health benefits for the welfare of living children and mothers, and the possibility of increased savings and investment by the family for its own future welfare. But the pressures of increased numbers of families on the size of farms, and on young men to leave the village in search of a livelihood, will not diminish until the smaller numbers of children become adults.

Goals of Fertility Control Policies

Developed and less developed countries can be differentiated almost as well by their birth rates, proportions of children, and rates of population growth as by per capita income and other socioeconomic measures. In all developed countries there are less than 20-25 live births per 1,000 people per year, and rates of natural population increase (the difference between birth rates and death rates) are usually lower than 15 per 1,000 per year, which means that the times required for the population to double in size are about 50 years or more. Nearly all less developed countries have birth rates higher than 30 per 1,000, and rates of natural increase higher than 20 per 1,000, with doubling times of less than 35 years.

The principal objective of national fertility control policies in less developed countries is to facilitate economic and social development. It appears reasonable, therefore, to select as the goal of these policies a reduction in fertility and rate of population growth *within the next 2 decades* to a level in the range of that in more developed economies.

We are unable to demonstrate quantitatively the extent to which such a marked reduction in fertility and rate of population growth would influence the rate of development. We are certain only that in all developed societies such a decline occurred during the course of their development. Birth rates in many present developed countries were relatively low even in the early stages of development, and the consequently low proportion of children to adults may have been an important factor in facilitating economic growth.

It is true that the decline in fertility in most of the now developed countries took place over a much longer time span than the 2 decades we have suggested, but the example of Japan, where birth rates decreased by nearly 50

percent from 1948 to 1960, and the rapid rates of decline in Taiwan and South Korea show that under present-day conditions a speedy fall in fertility rates is possible. Today's unprecedented rates of population growth make it urgently desirable. The drop in birth rates in Taiwan and South Korea also indicates that a high level of development is not a necessary condition for fertility decline. A condition that may be equally effective is a rapid rate of economic growth, which allows for social mobility, encourages rising aspirations among the people, and permits the allocation of sufficient resources for fertility control programs and for better communications leading to faster diffusion of information about family planning.

A possible objection is that these fertility ceilings might imply population decline or an undesirably slow rate of population growth in high-mortality nations with low population densities and that it would be unrealistic or unwarranted to expect these nations to endorse such a prospect through deliberate policy. The objection appears to us to have no practical relevance. The overwhelming evidence is that death rates can be brought down greatly and rapidly in low income, high fertility regions throughout the world, by a combination of socioeconomic and public health measures that are economically feasible.

An objection to proposed reductions in population growth rates made by some political leaders is that sheer numbers of people are a prerequisite, or at least an essential element, of political power internationally, especially for small nations. Such power considerations are often claimed to be associated with the achievement of social and economic objectives (such as a sufficiently large market for industrial products) or to override them as policy priorities when the two are in conflict.

There can be no effective rebuttal to those who would knowingly endure the socioeconomic burdens that arise from excessively growing populations in the hope that added numbers will contribute to national power. But the weight of relevant policy considerations seems to us to fall decisively in the opposite direction. First, few, if any, individual goals and certainly no national goals are ever absolute, or independent of the need for weighing priorities. Whatever the prospects for enhanced power or market through added numbers may be, the hoped for benefits must be judged in full awareness of the political, social, and economic costs of too rapid population growth. Second, modernity, not population size or growth, is the strategic determinant of a nation's political and economic status internationally.

A third objection, coming from almost the opposite end of the opinion spectrum is that any fertility target implying a positive rate of population growth is a false or deceptive policy prescription. A correct policy, according to proponents of this view, would aim at zero growth rates everywhere, the more so in the less developed nations since these have a much longer way to go from present vital rate levels and suffer much more severely the adverse

consequences of excessive population increase (and often of population size) than do the high income, low fertility nations. Our reply to these claims would not be that they need be refuted but that they are essentially irrelevant for policy purposes.

Associated Goals of Family Planning Programs. Governmental family planning programs may have other goals than reducing population growth by lowering birth rates, though this is a prime objective in many less developed countries, particularly in Asia. These other objectives include

1. increasing the ability and freedom of married couples (particularly poor or ignorant ones who do not have access to private medical care) to determine the number and spacing of their children;
2. reducing the number of illegal (and therefore often hazardous or even fatal) abortions by enabling women who do not want to bear a child to substitute safe contraceptive methods for abortion;
3. improving the health of mothers by helping them avoid too many or too closely spaced pregnancies;
4. reducing the number of illegitimate births;
5. protecting the health and welfare of children by persuading and helping parents to limit the size of their families and to lengthen the interval between births; and
6. helping to alleviate poverty by reducing the economic burden on parents created by large numbers of children.

Criteria for Fertility Control Policies

Before adopting a particular policy to reduce fertility, governmental leaders need to ask themselves several kinds of questions, including whether the policy is politically acceptable to most people, how effective it will be, and whether it is economically and administratively feasible. But the most fundamental questions are ethical: Will the policy enhance the freedom of human beings as individuals, and will it advance justice for all human beings as members of society? These two ethical ideals of individual freedom and distributive justice often are, or seem to be, more or less incompatible. The task of lawgivers throughout history has been to strike a workable balance between them. In establishing a population policy, this reconciliation will be best made if the policy proceeds from the following criteria:*

1. allows for freedom and diversity;
2. where possible, fosters other goals worth supporting for their own sake;
3. does not place unnecessary burdens on innocent people, particularly on children;

*Bernard Berelson, "Beyond Family Planning," *Studies in Family Planning*, 38, February 1969. pp. 1–16.

4. is helpful to deprived and disadvantaged people;
5. is comprehensible to those who are directly affected;
6. shows respect for moral values held by people concerning children and the family; and
7. has as its objective not only economic growth but reductions in poverty, increases in welfare, and conservation of the environment.

Proposed fertility-reduction policies and alternative lines of action need to be examined in the light of these considerations. The problems in any particular case are complex because they require giving different weights to these seven factors and possibly to others as well.

Free Access to Materials, Information, and Services for Fertility Control. Clearly, family planning programs, designed to give full freedom to individual couples to determine the number of their children and the spacing between births, meet several of these criteria. They enhance the freedom of human beings as individuals and, indeed, give this freedom a new dimension, particularly if wives participate equally with husbands in making the decisions. Repeal of laws restricting abortion and free availability of medically safe abortions would further enhance the freedom of individual women and of married couples, and should be considered in those countries that have sufficient medical manpower and hospital facilities and in which public attitudes permit. New approaches to safe induced abortion need to be found in order to lessen the need for medical manpower and hospital facilities.

It is today possible for a full range of acceptable, easily used, and effective means of preventing births to be provided by governments to all persons of reproductive age, if necessary at nominal or no cost. Information on all these means of preventing births, on the economic, social, and health benefits of small family size, and on the cumulative nature of the burdens caused by large families can also be widely disseminated. Steps and actions can be taken to foster broad social legitimization and support of birth control, including, when circumstances permit, medically safe abortions.

Other Policies and Programs

In general, the benefits and costs for society as a whole—that is for all families and individuals in the society—of a child added in one family will be different from those for the parents. These differences* justify social intervention to influence the fertility behavior of the parents. (Another justification for such intervention is that many families need help to recognize and serve their own interests.)

Many specialists are convinced that governmental population policies to limit fertility must go beyond furnishing contraceptive materials, services, and information to individual couples. If these couples, given full freedom of

*Called "externalities" by economists.

choice, on the average decide to have so many children that birth rates and rates of population growth remain high, then the economic and social development of the nation as a whole may be impeded and coming generations of human beings may be handicapped by their very numbers.

The freedom of husbands and wives to make reproductive decisions must, therefore, be tempered by concern for the rights and interests of others. The first and most obvious interest to be protected is that of the children already born within the family. The birth of additional children may affect them adversely in a number of ways, as we have seen. Next come all other members of the society whose economic welfare and social well-being are lessened by rapid population growth, and the younger and subsequent generations, whose opportunities will be diminished by the economic stagnation and loss of amenities caused by this growth. Finally, the interests of other nations and societies must be taken into account, because all nations ultimately make demands on the same pool of resources.

Governments have an obligation to protect the interests of all these groups against excessive reproduction by individual parents. One of the most difficult of population questions relates to designing and justifying governmental policies and procedures to accomplish this end.

Numerous policies have been suggested, some of which are discussed in the sections that follow.

Creation of a Small Family Norm. One policy that would appear to present a minimum restriction on individual freedom and to be well within the generally accepted practices of governments is to encourage private tastes, preferences, expectations, and attitudes toward a small family norm. Educational efforts for this purpose at the community level involve training of local leaders to explain the need for reducing fertility to other members of their communities, group discussions led by family planning workers, and personal persuasion of individuals by these workers. In addition to community-level programs, campaigns of public education and communication through television, radio, the press, outdoor advertising, and other media have also been undertaken. Such community and public efforts are accepted as legitimate components of population programs by many of the less developed countries.

Research on Fertility Control. A policy of generous support of research to improve the acceptability and effectiveness of means of contraception and contragestation (prevention of implantation or development of the fertilized ovum), to achieve reversible sterilization, to find ways of determining the sex of the embryo at about the time of conception, and on social means of achieving fertility decline can be thoroughly justified on both ethical and practical grounds.

Like applied research in agriculture, research in human reproductive biology and psychology should be supported by governments, as should research on other aspects of reproductive behavior. The governments of the developed

countries can make very important fundamental contributions to knowledge in this field, but cooperation between developed and less developed countries, and support by the United Nations, its specialized agencies, and other international organizations are needed to accelerate applied research and application, especially social and psychological research and development and testing of new contraceptive methods.

Welfare Policies Leading to Reduced Fertility. The decline in fertility in the Soviet Union, Europe, and North America that took place during the 19th and 20th centuries, and more recent declines in Japan and in some less developed countries, including Taiwan, South Korea, and Costa Rica, strongly indicate that married couples will limit the size of their families if they believe it is in their interest to do so and if means for controlling their own fertility are available to them. The parents' perception of their interest and their corresponding actions depend in part on social traditions and intuitive behavior patterns, as well as on conscious rationality.

Children provide both economic and psychic or social benefits to their parents and to other children in the family. During childhood and youth, they may contribute to family income by working with the family on a farm or in the production of handmade goods, or in a job outside the home. Those children who survive their parents can contribute to their parents' security in old age. Moreover, aside from these economic gains, it is part of our inheritance as human beings that most people like children and want to have some of their own. The psychic rewards of a family life enriched by children are reinforced by social norms, particularly in traditional societies with their extended or clan families and the many benefits conferred by kinship. In addition, the psychic and social costs of preventing births in a society without a high level of contraceptive technology are extraordinarily large, because they almost inevitably involve multiple induced abortions, late marriage, separation of the marriage partners over long periods, or some unsatisfactory modification of sexual relationships.

Children also produce costs, including the money costs of pregnancy and delivery, of feeding, clothing, housing, medical care, and education; the "opportunity cost" of the time and effort spent by parents to bring up their children (the magnitude of this cost depends upon the opportunities that exist for the parents to gain desired goals from other uses of the same time and effort); and the deprivation and health consequences to the mother and her children resulting from an additional child.

Both benefits and costs, as perceived by the parents, will vary with the number and sex of living children in the family. Probably most of the perceived benefits from an added child are highest when the number of children in the family is small. The incremental perceived benefits become less as the number of children increases. Some of the incremental costs of an added

child also diminish as the number of children in the family increases, but others, such as the effects on physical and mental health and development, tend to become larger. In those countries, including most of Asia, in which there is a strong preference for sons, the perceived benefits from gaining at least one or two sons will often lead families to risk assuming the costs of several daughters.

Changes in the conditions or way of life that reduce the benefits and increase the costs to the parents of having children, and/or make it easier not to have children, will tend to reduce fertility. Among these variable factors are

1. family income;
2. level of economic, social, and educational development of the society;
3. agricultural versus urban occupation and habitation;
4. possibility and desire for social and economic mobility;
5. availability of arable land and agricultural technology;
6. child labor and compulsory education laws;
7. availability of social security or old-age insurance;
8. employment opportunities for women;
9. status and decision-making ability of women in the society;
10. life expectancy of a newborn child, particulary the probability of survival during infancy and childhood; and
11. availability, effectiveness, and acceptability of means for preventing a birth.

Changes in the first five of these factors are affected by all government policies aimed at economic growth and social development, and are largely determined by the rates of economic growth. But several specific governmental policies and programs which have improvement in welfare as a primary objective will also lower the benefits and increase the costs of having children and are therefore also policies for limiting fertility. These policies are socially beneficial as an integral part of modernization and can be so evaluated quite apart from any effects they may have on fertility. On the other hand, although they are statistically correlated with relatively low or declining fertility, the causal relations are not entirely clear. The quantitative magnitude of the impact on fertility and the time required for this impact are uncertain. Among these multi-objective welfare policies are the following:

Laws prohibiting child labor. The parents lose the benefits of their children's earnings, and their costs are increased because they must support their children rather than letting them pay their own way.

Compulsory education and provision of educational facilities. Children in school have greater material needs; they are less beneficial to their parents because they cannot work when they are in school; and often the parents must pay part or all of the cost of education. Education also has a long-range effect. Educated people, especially educated women, have fewer children

than those who are not educated, probably because they perceive their interests differently.

Social security, old-age insurance, and pensions. If old people are supported by the state or through insurance or pension schemes, parents do not have to anticipate depending on their children for income in their old age. The economic incentive for having children is markedly lessened.

Employment opportunities for women. If employment outside the home is available to women, the opportunity costs of having children are increased. A woman who must stay home to take care of her children must forego the income she could earn outside the home. Educational and employment opportunities for young women give them an alternative to early marriage and childbearing, and the age of marriage will tend to rise, with a corresponding lowering of fertility rates. This is clearly occurring in certain districts of the state of Punjab in northwestern India, where the average age of marriage of women has risen steadily from about 17 years in 1956 to over 20 years in 1969, as education and job opportunities for young women in teaching, nursing, and other occupations have opened up. In general, however, an expansion of employment opportunities for women is difficult in less developed countries where unemployment and underemployment are already widespread and the size of the labor force is rising more rapidly than the demand for labor.

Improvement in the status of women. Improving the legal status of women through property, divorce, and inheritance laws, giving women the right to vote and facilitating their exercise of voting rights, and secularization of the marriage contract all tend to give women both a greater share in decision-making about the size of their families, and alternative purposes and opportunities to childbearing, thereby reducing the benefits of having children. By widening their horizons and their circle of communication, women are enabled to obtain better information on means of limiting their own fertility and the reasons for doing so.

Improvement in maternal health. Closely related to improvements in the social status of women are health services aimed at reducing maternal mortality and morbidity. These are both markedly affected by the number and spacing of births experienced by the mother. Policies aimed at improving maternal health should therefore include provision of information and materials for reducing fertility.

Reduction of infant and child mortality. High infant and child mortalities are characteristic of nearly all less developed countries. Considerable reduction is possible through improvements in nutrition, innoculations against infectious disease, and other public health measures. When average infant and child mortalities are high, the uncertainty faced by individual parents concerning the number of their children who are likely to survive is also high. Parents may compensate for this uncertainty by accepting the cost of having

"extra" children. Policies and programs aimed at reducing infant and child mortality considerably below present levels, therefore, may be an essential underpinning of governmental programs for fertility control.

Several fiscal and other government policies may also have a direct effect on the costs and benefits of having an additional child. Some of these policies are listed here with a tentative evaluation:

Village financing of education, health, and welfare services. In many less developed countries, the governments are unable to raise sufficient taxes to pay for the expansion of education required to raise enrollment ratios and to keep up with the rapid increase in numbers of children. At the same time, the demand for education among rural people has greatly increased. To meet this demand, it may be necessary to pass part of the responsibility for paying for education to the village level of government. Besides making more education possible, this policy would have the further effect that the villagers would become sharply aware of the costs of having large numbers of children, and would more clearly perceive their interest in lower fertility rates. The same procedure may be necessary and desirable, though to a lesser extent, for public health and welfare services.

Lowering the availability of housing. At least in some countries, the availability of housing appears to affect family formation and the fertility behavior of individual couples in the urban environment. At the same time, housing construction competes for scarce material and skilled labor with other industries needed for economic and social development. In these circumstances, governmental allocation of resources away from housing and toward increasing the means of production in other industries may help reduce fertility. The same result might be obtained by placing occupancy ceilings on housing, that is, limiting the number of people permitted to occupy a given amount of living space.

Military and national service. For national defense and other reasons, many nations require a large proportion of young men to serve in the armed forces. It has been observed that this tends to reduce fertility, at least in part by widening the horizons and the education of the draftees. Compulsory or voluntary national service that fully utilizes the energies and abilities of young women as well as young men could furnish an attractive alternative to marriage and would thus help to postpone the average age of marriage and childbearing—thereby leading to a significant lowering of fertility rates.

Tax and welfare disincentives. Various tax and welfare disincentives have been suggested, for example: abolition of income tax deductions for more than two or three children, an added tax for more than three children; or withdrawal of maternity benefits and family allowances for all but two or three children. These all need careful consideration on ethical grounds: unless a tax were strongly graduated by income, the rich would be affected only slightly, but the poor would be seriously hurt, and the main impact would be

on innocent people, namely on the children of large families among the poor, who, as we have seen, are already deprived.

Material incentives for fertility control. Some economists have calculated that nations with a surplus of unskilled labor will save a substantial sum for each birth prevented. From these calculations have sprung a number of plans to share this savings with couples who refrain from bearing additional children. In other words, some kind of payment in money, goods, services, or deferred income would be given to couples in which the wife does not become pregnant.

Under one plan, a married woman under 40 with at least one child would be paid 25¢ a month for the first 4 months she is enrolled in the plan, 50¢ a month for the second 4 months, with payments rising to $10 per year as long as she remains nonpregnant and under 40. Women enrolled in the plan would not only get quarterly payments but also be provided with comprehensive medical services. Under another plan, developed at Ghandigram in India, rewards for nonpregnancy would take the form of community improvements rather than payments to individuals. Under still another plan, couples with, say, three children or fewer at the end of their childbearing period would be entitled to an old-age pension. A fourth plan would provide an educational bond for parents with fewer than a designated number of children.

So far, none of these schemes has been tried even on a pilot basis. Officials of a number of governments have expressed interest in such experiments; others regard them as seriously questionable on ethical grounds. Plans proposed so far seem expensive and difficult to administer; and, until a number of large-scale pilot projects have been attempted to determine their feasibility and acceptability, whether they will induce a significant change in behavior cannot be determined.

The ethical implication of any proposal must also be carefully considered from the point of view of human dignity and distributive justice. Pensions in their old age to parents who have had less than a certain number of children would appear to create little injustice and in the long run might be more than justified by the benefits for all individuals in the society.

Involuntary fertility control. Various schemes for involuntary fertility control have been suggested, including "putting something in the water" that would lower the average fertility of the population, compulsory sterilization of parents after they have acquired more than three or four living children, or compulsory sterilization for all people, which would be reversible only by obtaining a license from the government to have a child. Aside from their political inviability or technical impossibility at the present time, these proposals represent gross violations of individual freedom and would appear to be justifiable on the grounds of distributive justice only after all other methods of limiting population growth have failed.

International sanctions. International pressures on governments of less developed countries to expand and intensify their population control programs, backed up by such sanctions as the denial of food aid to nonconforming countries, have been suggested. Under present circumstances, such a policy would be highly counterproductive from a practical point of view, but it is equally open to condemnation on ethical grounds, because it would violate the principle of distributive justice by penalizing the children of the poorest classes in the poor countries, who are most vulnerable to malnutrition and starvation.

Free education for only two or three children in each family. In a country in which the resources are inadequate to educate all children, it would appear reasonable to place the burden of being not educated in such a way as to encourage parental responsibility, provided all couples had equal and adequate access to means of fertility control. The difficulty here is the practical one–the educational system in most less developed countries could not be so finely adjusted.

Policy Formation and Management

Population policies are a new and untested area for politicians and administrators, who have neither tradition nor public consensus to guide them. Moreover, because of the long-term quality of population policies, the governments of less developed countries, which are commonly pressed almost beyond their capability by urgent day-to-day problems that may threaten the very stability of regimes, have tended to put population problems and policies to deal with them into the limbo of things to be done when time permits. Most of the economists and planners who advise government leaders have had neither the statistical data nor the analytical tools to be able to fit population questions into their structure of analysis and planning.

The Special Character of Population Policies

These and other difficulties give a special character to the formation of population policies. To create a public consensus, they should be initiated by programs of public education and debate. Because population changes are fundamental to all aspects of the peoples' welfare, leadership needs to be taken at the highest political and government level. To serve national development goals, policies must be based on adequate demographic and economic data. Economic and other advisers need to learn new ways of thinking and new tools of analysis, illuminated by all the knowledge and understanding available in the field. Because population policies must be highly innovative, there is much room for experimentation, and because of their long-term

character, experimentation is feasible. But if this experimentation is to be useful, a great deal of attention needs to be paid to realistic evaluation of the results of policies and programs.

Policy Coordination

It is tempting to suggest that population policies are so important, fundamental, and far-reaching that they should be the province of a special ministry of population at the cabinet level within national governments. But the essence of population problems is their pervasive character. Population-responsive policies to deal with the effects of rapid population growth must be part of the responsibility of the ministries that deal with education, health, agriculture, urbanization, transportation, labor, housing, welfare, and even finance and defense. All these ministries need a sophisticated understanding of the ways in which population changes affect their areas of concern.

Similarly, government actions to reduce fertility can be expected to be most successful only if several kinds of population-influencing policies in education, health services, public law, food and nutrition, biological and social research, and social security are brought to bear simultaneously. This calls for coordinated planning and action by many different arms of government. The seat of coordination should be in the jurisdictionally neutral but administratively powerful unit of government that sets priorities in the light of politically established goals. In some countries this will be the planning commission; in others, the executive office of the president or prime minister; in others, a presidential council or commission. The burden of the coordinating task is to ensure that executive agencies with different primary missions manage their affairs through multi-objective population-influencing policies of the kind we have described so as to maximize their contribution to the national goal of fertility reduction.

Administration and Personnel for Population-Influencing Policies

This "systems approach" to population policy requires extensive training of managers, recasting of budgets, development of an international network for exchanging information and ideas, creation of professional standards and career opportunities for population planners and administrators, and organization and funding of many different kinds of research.

As in all fields of government action, population-influencing policies call for the allocation of scarce resources and the setting of priorities. The scarcest resources in most less developed countries are competent administrators, particularly at the lower levels and the front lines of action. Immediate priority is likely to be given to policies and programs that can be combined with other ongoing activities and do not call for the creation of new administrative services: for example, provision of family planning services through existing

public health clinics. But policies to control fertility are so important, and so specialized, that in the long run it will be necessary to train, equip, and set in place new administrative cadres.

In part because experienced, specialized personnel for fertility control programs are very scarce but largely because physicians have long thought of birth, like illness and death, as their province, and the public has agreed with them, physicians and other medically trained personnel should be given education and training in population problems as well as methods of fertility control. Their enthusiastic concurrence in fertility control programs is essential in the early stages.

Public information and education are also basic elements of population-influencing policies, whether the concern is for fertility, mortality, or migration. Education and motivation of parents to realize their options, rights, and duties to their own family and to the community must be an integral part of fertility control programs. Specialists in adult and health education and in public communications through newspapers, radio, television, voluntary associations, community leaders, and other means are needed to develop, carry out, and evaluate these tasks.

Multilateral and Bilateral Assistance

Governments can learn from each other's experience in this new field, and they can be stimulated to action by confrontation with effective policies of other countries. The United Nations and its specialized agencies, especially the World Health Organization and UNESCO, can be immensely helpful in this process of intergovernmental learning.

Developed countries can play a major role through bilateral technical assistance in helping to carry out population policies that a developing country would like to establish but which call for greater material, technical, and human resources than are available in the country.

Role of Nongovernmental Organizations

Private agencies dealing with health, family planning, migration, and urbanization problems should be encouraged to continue even after government enters these fields. The private agencies should be looked to for innovation, experiment, and approaches not feasible for governments, rather than for duplication of government services.

Stages of Implementation for Fertility Control Policies

Just as other government policies and programs should be subject to annual review and modification in the light of changing conditions, fertility control policies also need to be kept under scrutiny and frequently modified. In most less developed countries, the first stages of policy will depend on a

very considerable improvement in census and vital statistics and their analysis. Public education and debate should be encouraged as soon as possible. Trial programs should be initiated and carefully evaluated. A nationwide organization must be developed, which will function differently in cities than in rural areas. Accurate record-keeping is important, but it should not be pushed too hard at first, nor should quotas and other high-pressure devices be used until a satisfactory methodology has been developed and success seems assured. The program must not move very much faster than the people whom it serves. Their attitudes, values, prejudices, and lack of information must be treated with respect and compassion.

Fertility control policies can be effective only if they change the reproductive behavior of many individual couples. To a large extent in the less developed countries this calls for the efforts of thousands of well-trained, knowledgeable, front-line workers in continuing personal contact with individual men and women in tens of thousands of villages and towns. The problems are somewhat like those of agricultural extension services in changing the agricultural practices of small, independent farmers, and quite different from those of malaria control or mass innoculation programs, which require a minimum of personal contacts. Much of the work is pedestrian, involving meticulous attention to detail and the expeditious solving of day-to-day problems as they arise. Yet the reduction of birth rates in Taiwan and South Korea during the last few years is in considerable part the result of such patient, careful efforts by people at all levels in family planning organizations.

V

Recommendations

This study of the consequences of rapid population growth and their policy implications has led to the policy recommendations that follow. Having offered a number of options in the preceding sections, we now select those we think are the most viable for the near future to help societies cope with and influence population trends.

We are deeply conscious that the issues and actions associated with population questions are of enormous importance in the lives of individual men and women. For this reason we base our first recommendation on the ethical premise that freedom and knowledge should be extended so that people can act in their own best interest—both individually and collectively. It seems quite contrary to society's highest aspirations for men to assume, as some do, that their salvation can be accomplished only through coercion.

Recommendation One: Freedom To Determine Family Size

We urge that governments extend to women and men the freedom and means to determine the number of children in each family and the knowledge which will help them exercise responsible parenthood.

1. A full range of acceptable, easily used, and effective means of preventing births ought to be made accessible by governments to all persons of reproductive age; if necessary, at nominal or no cost.

2. Wide dissemination of full information on all the means of preventing births, on the economic, social, and health benefits of small family size, and on the cumulative nature of the burdens caused by large families should be given high priority both by governments and private institutions.

Information and advice about family planning must be factual and based as far as possible on the special conditions in each country. Very few countries come even close to fulfilling these ideals, not even the developed countries, which can most easily afford their costs. Real freedom of choice of family size with access to the best modern technology of fertility control is completely beyond the reach of well over half a billion families on the earth today.

3. Legal and social barriers to fertility control should be promptly removed and broad social acceptance and support of fertility control should be fostered, including, where health services permit, medically safe abortions and sterilization.

Recommendation Two: National Population-Influencing Policies

To serve national objectives of economic development, public health and welfare, and environmental conservation, we recommend that all nations establish policies to influence the rate of growth of their populations and to adopt politically and ethically acceptable measures toward this end that are within their administrative and economic capability. For most nations of the world the major goal of population-influencing policies should be a reduction in fertility.

Responsible population-influencing policies require adequate demographic data and analysis and will always take into account the attitudes and felt needs of the people. They can be formulated best in the light of economic and political analysis of the complex interrelationships between population growth and economic and social development and with full understanding of the benefits to individual families of a small number of children in each family.

1. The highest level of government is the natural locus for leadership in the formulation of population-influencing policies and the coordination of policy-implementing programs.

Many departments of government, including those concerned with education, health and welfare, public laws, food and nutrition, biological and social research, housing, social security, and national service, should be involved in planning and carrying out welfare and other policies that have fertility reduction as one objective. These policies can best be coordinated and resources allocated for their implementation by the planning or budgeting agencies of governments if they are to make a maximum contribution to the national goals of fertility reduction.

2. Public policies and programs pertaining to human fertility require review at frequent intervals to facilitate modification in the light of changing conditions.

There is much room for experimentation because such programs are highly innovative, but the experimentation will be most useful only if the results are realistically evaluated. If they are successful, the programs will pass through a series of stages. At all stages, the attitudes, values, and level of information of the people being served should influence the program planners.

The effects of population shifts, urbanization, mortality reduction programs, and other population-influencing factors must be carefully weighed as

conditions change, because age and sex distribution patterns, as well as population density, create a continuously changing matrix for policy.

Recommendation Three: Short-Term Growth Rate, Death Rate, and Birth Rate Goals.

First: We urge that countries in which rapid population growth is now occurring seek to reduce their rates of natural increase to less than 15 per 1,000 per year over the next 2 decades. Relatively low-fertility countries that are already growing more slowly than this should seek to approach more closely a stationary population level over the next 20 years.

Second: We urge that in high-mortality countries, modernization policies sufficient to accomplish a reduction in fertility be accompanied by policies of equivalent priority in order to reduce death rates to less than 10-15 per 1,000 per year.

Third: We urge that high-fertility countries set as a goal of population policy the reduction of birth rates within the next 2 decades to less than 25-30 live births per 1,000 people per year.

What constitutes a rational fertility level will obviously vary with circumstances, but we urge that significant limits can and should be identified. Thus it seems to us that there are clear disadvantages of a national birth rate above 30 live births per 1,000 people per year. The weight of evidence and rational presumption concerning socioeconomic consequences strongly favors a birth rate of 25 or less over one of 35 or higher. It is unquestionably desirable for the welfare of children and mothers to reduce the number of children ever born in the average family to a much lower level than the range of six or more that now exists in many countries.

Within the proposed limits on birth rates, individual societies and nations would find ample room for specific policies of fertility reduction that meet their criteria of cultural self-determination and socioeconomic prudence.

As death rates are brought below 10-15 per 1,000 in present high-fertility, high-mortality countries, birth rates should be correspondingly reduced. For present low-fertility countries, the recommendation implies an effort to approach a "replacement level" of fertility.

The magnitude of the policy challenge underlying the attainment of the above proposed limits on fertility is extraordinary. For the large majority of the world's population and for nearly all less developed nations, a drop in the birth rate below 25-30 per 1,000 per year would represent a historic break with the past and would be spectacular if accomplished within 1 or 2 decades. Demographically, the fertility targets being urged here represent a call to revolutionary demographic transition, moderated by a precautionary regard for cultural pluralism, and by a generous allowance for different socioeconomic welfare goals in different parts of the world.

Moreover, the central point of the recommendations is that they contemplate the near future—the next 20 years. From a practical point of view, little is gained by proclaiming the virtues of very long-term demographic equilibrium conditions, even if these virtues could be demonstrated uncontestably. Indeed, we see room for harm if such an approach were to usurp the place of considered deliberation by national leaders about needed next steps toward demographic amelioration. A policy approach that proposes an unrealistic goal and threatens disaster if it is not adopted is likely to promote, rather than allay, apathy or opposition.

Recommendation Four: Accelerating the Trend toward the Smaller Family

Governmental and private efforts should be expanded to accelerate the trend toward the smaller family and the sense of individual responsibility toward society.

Planned and coordinated factual campaigns of public education and communication through television, radio, the press, outdoor advertising, voluntary associations, community leaders, and personal explanation by family planning workers are means to accomplish this end.

True freedom to determine family size can be realized only if it is, like all other human freedoms, tempered by the concern of the individual for the rights and interests of others. The essence of the matter is to protect both society and the individual. In this instance society needs protection from the undesirable effects of high fertility and the individual needs protection from ignorance, coercion, and inequitable access to the technical resources of society.

Recommendation Five: Multi-Objective Policies

We recommend that many of the social policies of governments include among their objectives that of increasing the desirability of small families.

The attitudes of parents toward family size are most likely to change if the social environment, opportunities, and personal relations are altered in ways that help parents perceive their interest differently.

Policies that increase parents' interest in small families, while at the same time serving other desirable goals, include laws prohibiting child labor; compulsory education and provision of educational facilities; social security, old age insurance, and pensions; employment, educational, and career opportunities for women; improvement in the status of women; improvement in maternal health; and reduction of infant and child mortality.

Other policies, related to methods of financing education and welfare services, allocation of resources and occupancy levels for housing, and various

types of compulsory or voluntary national service, can likewise be directed toward reducing fertility, as well as toward other objectives.

Population policies should be understandable and widely acceptable to the people. They should help children and the poor and deprived, not place burdens on them. This approach in reducing fertility is particularly relevant for policies involving tax and welfare incentives and disincentives. The alleviation of poverty and greater welfare both for children and adults is the ultimate objective and should be clearly perceived as such by the people.

Recommendation Six: Population-Responsive Policies

We urge that policies designed to deal with the effects of population change be established by government departments concerned with education, health, agriculture, urbanization, transportation, labor, housing, welfare, finance, and defense.

Economists and planners who advise these agencies can enhance their effectiveness greatly by seeking greater knowledge and understanding of the ways in which population changes affect their areas of concern and by developing the demographic and economic data and analytical tools needed for this purpose.

The changing effects of age and sex distribution patterns and shifts in population density make population-responsive policies ever vulnerable to short- and long-term demographic changes, many of which can be anticipated by close examination of trends. Policymakers and planners must be alert to these changes as they affect current legislation and administrative practice and as they set the stage for the future.

Recommendation Seven: Population Policy in the International Context

We recommend that developed countries expand their multilateral and bilateral technical assistance to developing countries by providing material, technical, and human resources to help carry out policies and programs aimed at lowering mortality and fertility, improving the conditions of urbanization, and solving other population problems.

It is vital to recognize, however, that population programs and support for fertility limitation cannot be regarded as a substitute for long-term assistance designed to raise people's standards of health, education, consumption, and welfare. A rapid decline in fertility may not be possible without rising levels of education and communication.

Technical assistance can often be effectively provided directly by a developed country to a developing one or by one developing country to another.

The developed countries cannot fail to recognize the long-term nature of many aspects of population problems and their profound relationship to

national aspirations in the developing countries. Multilateral and bilateral programs of technical assistance require continuity over many years and should emphasize economic and social development as a primary goal.

By virtue of its leadership in population research and its commitment to the enhancement of the lot of the poor of the world, the United States of America is in a unique position to provide continuing support on a long-term and unequivocal basis to help other countries and international agencies carry out voluntary fertility-limiting programs.

1. The United Nations and its specialized agencies, particularly the U.N. Fund for Population Activities, the World Health Organization, and UNESCO, ought to give high priority to helping their member states learn from one another about population goals and the conduct of fertility-reducing programs.

Information exchange among countries has been one of the most successful activities of the United Nations agencies in other fields, and these agencies are uniquely qualified for this function. Among the promising possibilities is the "confrontation" technique of the Organization for Economic Cooperation and Development.

2. The United Nations Development Program and other U.N. agencies and regional organizations, such as the Pan American Health Organization and the Organization of American States, are urged to greatly strengthen their staffs and procedures to increase the effectiveness of their technical assistance for fertility-reduction programs. Multilateral assistance through intergovernmental agencies will often be more acceptable than bilateral assistance to developing countries; therefore it is important to improve its quality.

3. A United Nations agency (such as the World Bank) should take the lead in preparing a world budget of the needs during the next 2 decades to carry out programs of fertility and mortality reduction in all developing countries.

Such a world budget would be comparable to the *Indicative World Plan for Agricultural Development* prepared by the Food and Agricultural Organization. It is suggested that it include, among other things, provision for research; training; collection and analysis of demographic data; public education and communications; contraceptive materials; services of physicians, paramedical and other personnel; transportation and other expenses; program evaluation; and welfare policies that would reduce the desired numbers of children and are feasible in different countries. It will be important to try to forecast alternative sequences of program development and identify potential sources of funds and modes of financing; particularly the requirements for technical and financial assistance among countries.

4. We applaud the work of foundations, voluntary associations, and other private organizations and urge that they be encouraged in research and action programs for fertility reduction.

The private agencies are a superb source to be looked to for innovation, experimentation, and approaches not feasible for governments, rather than for duplication of government services.

Recommendation Eight: the Need for Research

To the student of population problems the need for further research is painfully obvious. Our study on the policy implications of rapid population growth has demonstrated this need to us with extraordinary clarity. It is the habit of scholars to call for more research, but the case for population research appears to us to be compelling for the people of the world. Therefore:

First: We urge that governments, in both developed and developing countries, support research on reproductive physiology and methods of fertility control and on the economic, social, and health factors that determine fertility behavior.

International cooperation in such research can contribute greatly to its effectiveness because the many types of research needed in different cultures, the interdisciplinary character of such research, and the numbers of institutions and people involved require global exchange of information and mutual assistance.

Second: In addition to strengthening ongoing efforts, we propose that a number of international research centers on population problems be established and supported, at least in part, through intergovernmental technical assistance mechanisms.

Third: We urge governments and private agencies to expand university research and teaching on the role of demographic factors in economic and social change.

Problems concerning which more information and understanding are needed include the consequences of population change for economic and social development; urbanization and internal migration; labor policy and industrialization; agriculture and nutrition; health and welfare; education and communications; natural resources and environmental quality; and conflicts among ethnic, linguistic, and other social groups.

These recommendations and our comments are not designed to present a comprehensive solution to the world's population problems; they are simply our selection of the most useful options as of summer 1970. We have, as one result of this study, come to realize that comprehensive closure on most aspects of population is impossible simply because we do not know enough. This is our best estimate of the immediate needs in terms of both prompt action programs for the next few years and the research required to make future policies more effective through an expanded base of knowledge.

Population And The American Future

The Report of
The Commission on
Population Growth and
the American Future

Preface

For the first time in the history of our country, the President and the Congress have established a Commission to examine the growth of our population and the impact it will have upon the American future. In proposing this Commission in July 1969, President Nixon said: "One of the most serious challenges to human destiny in the last third of this century will be the growth of the population. Whether man's response to that challenge will be a cause for pride or for despair in the year 2000 will depend very much on what we do today." The Commission was asked to examine the probable extent of population growth and internal migration in the United States between now and the end of this century, to assess the impact that population change will have upon government services, our economy, and our resources and environment, and to make recommendations on how the nation can best cope with that impact.

In our Interim Report a year ago, the Commission defined the scope of our mandate: ". . . to formulate policy for the future"—policy designed to deal with "the pervasive impact of population growth on every facet of American life." We said that population growth of the magnitude we have experienced since World War II has multiplied and intensified many of our domestic problems and made their solution more difficult. We called upon the American people to begin considering the meaning and consequences of population growth and internal migration and the desirability of formulating a national policy on the question.

Since then, the Commission and staff have conducted an extensive inquiry. We have enlisted many of the nation's leading scientists in more than 100 research projects. We have heard from more than 100 witnesses in public hearings across the country and have met with experts in many days of executive meetings. And we are aware that population has become an active subject of consideration in a number of states in our country concerned about their future. We have come to recognize that the racial and ethnic diversity of this Commission gives us confidence that our recommendations—the consensus of our members—do indeed point the way in which this nation should move in solving its problems. Because of the importance of this matter, the Commission recommends that future federal commissions include a substantial representation of minorities, youth, poor citizens, and women among their members, including congressional representatives, and the commission staffs and consultants include significant numbers of minorities, youth, and women.

We offer this report in the hope that our viewpoints and recommendations will stimulate serious consideration and response by the citizens of this nation and of nations throughout the world to an issue of great consequence to present and future generations.

Chapter 1: Perspective on Population

In the brief history of this nation, we have always assumed that progress and "the good life" are connected with population growth. In fact, population growth has frequently been regarded as a measure of our progress. If that were ever the case, it is not now. There is hardly any social problem confronting this nation whose solution would be easier if our population were larger. Even now, the dreams of too many Americans are not being realized; others are being fulfilled at too high a cost. Accordingly, this Commission has concluded that our country can no longer afford the uncritical acceptance of the population growth ethic that "more is better." And beyond that, after two years of concentrated effort, we have concluded that no substantial benefits would result from continued growth of the nation's population.

The "population problem" is long run and requires long-run responses. It is not a simple problem. It cannot be encompassed by the slogans of either of the prevalent extremes: the "more" or the "bigger the better" attitude on the one hand, or the emergency-crisis response on the other. Neither extreme is accurate nor even helpful.

It is a problem which can be interpreted in many ways. It is the pressure of population reaching out to occupy open spaces and bringing with it a deterioration of the environment. It can be viewed as the effect on natural resources of increased numbers of people in search of a higher standard of living. It is the impact of population fluctuations in both growth and distribution upon the orderly provision of public services. It can be seen as the concentration of people in metropolitan areas and depopulation elsewhere, with all that implies for the quality of life in both places. It is the instability over time of proportions of the young, the elderly, and the productive. For the family and the individual, it is the control over one's life with respect to the reproduction of new life—the formal and informal pronatalist pressures of an outmoded tradition, and the disadvantages of and to the children involved.

Unlike other great public issues in the United States, population lacks the dramatic event—the war, the riot, the calamity—that galvanizes attention and action. It is easily overlooked and neglected. Yet the number of children born now will seriously affect our lives in future decades. This produces a powerful effect in a double sense: Its fluctuations can be strong and not easily changed; and its consequences are important for the welfare of future generations.

There is scarcely a facet of American life that is not involved with the rise and fall of our birth and death rates: the economy, environment, education, health, family life and sexual practices, urban and rural life, governmental effectiveness and political freedoms, religious norms, and secular life styles. If this country is in a crisis of spirit—environmental deterioration, racial antagonisms, the plight of the cities, the international situation—then population is part of that crisis.

Although population change touches all of these areas of our national life and intensifies our problems, such problems will not be solved by demographic means alone. Population policy is no substitute for social, economic, and environmental policy. Successfully addressing population requires that we also address our problems of poverty, of minority and sex discrimination, of careless exploitation of resources, of environmental deterioration, and of spreading suburbs, decaying cities, and wasted countrysides. By the same token, because population is so tightly interwoven with all of these concerns, whatever success we have in resolving these problems will contribute to easing the complex system of pressures that impel population growth.

Consideration of the population issue raises profound questions of what people want, what they need—indeed, what they are for. What does this nation

stand for and where is it going? At some point in the future, the finite earth will not satisfactorily accommodate more human beings—nor will the United States. How is a judgment to be made about when that point will be reached? Our answer is that now is the time to confront the question: "Why more people?" The answer must be given, we believe, in qualitative not quantitative terms.

The United States today is characterized by low population density, considerable open space, a declining birthrate, movement out of the central cities—but that does not eliminate the concern about population. This country, or any country, always has a "population problem," in the sense of achieving a proper balance between size, growth, and distribution on the one hand, and, on the other, the quality of life to which every person in this country aspires.

Nor is this country alone in the world, demographically or in any other way. Many other nations are beginning to recognize the importance of population questions. We need to act prudently, understanding that today's decisions on population have effects for generations ahead. Similarly, we need to act responsibly toward other people in the world: This country's needs and wants, given its wealth, may impinge upon the patrimony of other, less fortunate peoples in the decades ahead. The "population problem" of the developing countries may be more pressing at this time, but in the longer perspective, it is both proper and in our best interest to participate fully in the worldwide search for the good life, which must include the eventual stabilization of our numbers.

A Diversity of Views

Ultimately, then, we are concerned not with demographic trends alone, but with the effect of these trends on the realization of the values and goals cherished as part of the American tradition and sought after by minorities who also "want in."

One of the basic themes underlying our analysis and policy recommendations is the substitution of quality for quantity; that is, we should concern ourselves with improving the quality of life for all Americans rather than merely adding more Americans. And unfortunately, for many of our citizens that quality of life is still defined only as enough food, clothing, and shelter. All human beings need a sense of their own dignity and worth, a sense of belonging and sharing, and the opportunity to develop their individual potentialities.

But it is far easier to achieve agreement on abstract values than on their meaning or on the strategy to achieve them. Like the American people generally, this Commission has not been able to reach full agreement on the relative importance of different values or on the analysis of how the "population problem" reflects other conditions and directions of American society.

Three distinct though overlapping approaches have been distinguished. These views differ in their analysis of the nature of the problem and the general priorities of tasks to be accomplished. But, despite the different perspectives from which population is viewed, all of the population policies we shall recommend are consistent with all three positions.

The first perspective acknowledges the benefits to be gained by slowing growth, but regards our population problem today primarily as a result of large numbers of people being unable to control an important part of their lives—the number of children they have. The persistence of this problem reflects an effective denial of freedom of choice and equality of access to the means of fertility control. In this view, the population problem is regarded more as the sum of such individual problems than as a societal problem transcending the interests of individuals; the welfare of individuals and that of the general society are seen as congruent, at least at this point in history. The potential conflict between these two levels is mitigated by the knowledge that freedom from unwanted childbearing would contribute significantly to the stabilization of population.

Reproductive decisions should be freely made in a social context without pronatalist pressures—the heritage of a past when the survival of societies with high mortality required high fertility. The proper mission for government in this matter is to ensure the fullest opportunity for people to decide their own future in this regard, based on the best available knowledge; then the demographic outcome becomes the democratic solution.

Beyond these goals, this approach depends on the processes of education, research, and national debate to illuminate the existence of any serious population "problem" that transcends individual welfare. The aim would be to achieve the best collective decision about population issues based on knowledge of the tradeoffs between demographic choices and the "quality of life," however defined. This position ultimately seeks to optimize the individual and the collective decisions and

then accepts the aggregate outcome—with the understanding that the situation will be reconsidered from time to time.

The second view does not deny the need for education and knowledge, but stresses the crucial gaps between what we claim as national values and the reality experienced by certain groups in our society. Many of the traditional American values, such as freedom and justice, are not yet experienced by some minorities. Racial discrimination continues to mean that equal access to opportunities afforded those in the mainstream of American society is denied to millions of people. Overt and subtle discrimination against women has meant undue pressure toward childbearing and child-rearing. Equality is denied when inadequate income, education, or racial and sexual stereotypes persist, and shape available options. Freedom is denied when governmental steps are not taken to assure the fullest possible access to methods of controlling reproduction or to educational, job, and residential opportunities. In addition, the freedom of future generations may be compromised by a denial of freedom to the present generation. Finally, extending freedom and equality—which is nothing more than making the American system live up to its stated values—would go far beyond affecting the growth rate. Full equality both for women and for racial minorities is a value in its own right. In this view, the "population problem" is seen as only one facet, and not even a major one, of the restriction of full opportunity in American life.

The third position deals with the population problem in an ecological framework, one whose primary axiom asserts the functional interdependence of man and his environment. It calls for a far more fundamental shift in the operative values of modern society. The need for more education and knowledge and the need to eliminate poverty and racism are important, but not enough. For the population problem, and the growth ethic with which it is intimately connected, reflect deeper external conditions and more fundamental political, economic, and philosophical values. Consequently, to improve the quality of our existence while slowing growth, will require nothing less than a basic recasting of American values.

The numbers of people and the material conditions of human existence are limited by the external environment. Human life, like all forms of life on earth, is supported by intricate ecological systems that are limited in their ability to adapt to and tolerate changing conditions. Human culture, particularly science and technology, has given man an extraordinary power to alter and manipulate his environment. At the same time, he has also achieved the capacity virtually to destroy life on earth. Sadly, in the rush to produce, consume, and discard, he has too often chosen to plunder and destroy rather than to conserve and create. Not only have the land, air, and water, the flora and fauna suffered, but also the individual, the family, and the human community.

This position holds that the present pattern of urban industrial organization, far from promoting the realization of the individual as a uniquely valuable experience, serves primarily to perpetuate its own values. Mass urban industrialism is based on science and technology, efficiency, acquisition, and domination through rationality. The exercise of these same values now contains the potential for the destruction of our humanity. Man is losing that balance with nature which is an essential condition of human existence. With that loss has come a loss of harmony with other human beings. The population problem is a concrete symptom of this change, and a fundamental cause of present human conditions.

It is comfortable to believe that changes in values or in the political system are unnecessary, and that measures such as population education and better fertility control information and services will solve our population problem. They will not, however, for such solutions do not go to the heart of man's relationship with nature, himself, and society. According to this view, nothing less than a different set of values toward nature, the transcendence of a laissez-faire market system, a redefinition of human identity in terms other than consumerism, and a radical change if not abandonment of the growth ethic, will suffice. A new vision is needed—a vision that recognizes man's unity with nature, that transcends a simple economic definition of man's identity, and that seeks to promote the realization of the highest potential of our individual humanity.

The Immediate Goal

These three views reflect different evaluations of the nature of the population problem, different assessments of the viability of the American political process, and different perceptions of the critical values at stake.

Given the diversity of goals to be addressed and the manifold ramifications of population change throughout society, how are specific population policies to be selected?

As a Commission and as a people, we need not agree on all the priorities if we can identify acceptable policies that speak in greater or lesser degree to all of them. By and large, in our judgment, the policy findings and recommendations of this Report meet that requirement. Whatever the primary needs of our society, the policies recommended here all lead in right directions for this nation, and generally at low costs.*

Our immediate goal is to modernize demographic behavior in this country: to encourage the American people to make population choices, both in the individual family and society at large, on the basis of greater rationality rather than tradition or custom, ignorance or chance. This country has already moved some distance down this road; it should now complete the journey. The time has come to challenge the tradition that population growth is desirable: What was unintended may turn out to be unwanted, in the society as in the family.

In any case, more rational attitudes are now forced upon us by the revolutionary increase in average length of life within the past century, which has placed modern man in a completely different, historically unique, demographic situation. The social institutions and customs that have shaped reproductive behavior in the past are no longer appropriate in the modern world, and need reshaping to suit the new situation. Moreover, the instruments of population policy are now more readily available—fuller knowledge of demographic impacts, better information on demographic trends, improved means by which individuals may control their own fertility.

As a Commission, we have come to appreciate the delicate complexities of the subject and the difficulty, even the impossibility, of solving the problem, however defined, in its entirety and all at once. But this is certainly the time to begin: The 1970's may not be simply another decade in the demographic transition but a critical one, involving changes in family life and the role of women, dynamics of the metropolitan process, the depopulation of rural areas, the movement and the needs of disadvantaged minorities, the era of the young adults produced by the baby boom, and the attendant question of what their own fertility will be—baby boom or baby bust.

Finally, we agree that population policy goals must be sought in full consonance with the fundamental values of American life: respect for human freedom, human dignity, and individual fulfillment; and concern for social justice and social welfare. To "solve" population problems at the cost of such values would be a Pyrrhic victory indeed. The issues are ethical in character, and their proper solution requires a deep sense of moral responsibility on the part of both the individual family and the national community: the former in considering another birth, the latter in considering appropriate policies to guide population growth into the American future.

For our part, it is enough to make population, and all that it means, explicit on the national agenda, to signal its impact on our national life, to sort out the issues, and to propose how to start toward a better state of affairs. By its very nature, population is a continuing concern and should receive continuing attention. Later generations, and later commissions, will be able to see the right path further into the future. In any case, no generation needs to know the ultimate goal or the final means, only the direction in which they will be found.

**A separate statement by Commissioner James S. Rummonds appears on page 164.*

Chapter 4: The Economy

Does a healthy economy require a growing population? Would slower population growth hurt business or threaten workers' jobs? Would it help? How would the average person fare in economic terms if the rate of population growth approached zero?*

We have conducted research to determine what effects different rates of population growth are likely to have on the economic well-being of the nation. We compared the effects of the 2-child population projection with the effects of the 3-child projection. Our overall conclusions from this research are:

1. Major economic changes are on the horizon regardless of future changes in population growth rates.
2. The nation has nothing to fear from a gradual approach to population stabilization.
3. From an economic point of view, a reduction in the rate of population growth would bring important benefits, especially if the United States develops policies to take advantage of the opportunities for social and economic improvement that slower population growth would provide.

Income

Between now and the year 2000, increases in the productivity of workers are likely to result in such a large rise in average income that styles of life in the year 2000 will be qualitatively different from what they are today. It is expected that by the year 2000 average family income, now about $12,000, will exceed $21,000, in terms of today's dollars.[1] This is the projection, even if the work week were reduced to 30 hours, and even if the population grew at the 3-child rate.

The average individual's consumption is expected to be more than twice what it is today, whether the population grows at the 2-child or the 3-child rate. As income increases, people show an increased preference for services, such as education and health services, as compared with manufactured goods. So, the population of the year 2000 will boost its consumption of services faster than its consumption of manufactured goods.

The rate of population growth will have a significant effect on per capita income. Our research indicates that in the year 2000, per capita income may be as much as 15 percent higher under the 2-child than under the 3-child population growth rate. The main reason for the higher per capita income under the 2-child projection is the shift in the age composition resulting from slower population growth; as we saw earlier, people of working age will constitute a larger fraction of the total population under conditions of slower population growth. A secondary reason is that with lower birthrates the percentage of women in the labor force is expected to rise somewhat faster than it would otherwise. Taken together, these trends mean relatively more workers and earners, and relatively fewer mouths to feed.

The age effect arises from the fact that population replaces itself from the bottom up; and, if it is growing, it is adding more and more at the base of the age pyramid. However, growth in the population of working age is drawn from the smaller numbers of births that occurred 15 to 20 years earlier. When growth slows, it slows first at the base, and before long we see a narrowing of the difference between the number of births and the numbers annually entering the working ages. The ratio of workers to youthful dependents rises, the income they produce is spread among fewer people, and the average income available per person in the population consequently increases.

Of course, the same process eventually causes a rise in the percentage of old people in the population—those who have passed working age. But because of higher death rates at these ages, the increase in aged dependency offsets only part of the decline in youth dependency, and the overall result is still a major drop in total dependency and an increase in income available per person in the population.

Economic Growth and the Quality of Life

The use of income or output per capita as an indicator of the quality of life has been criticized on a number of grounds. One such criticism is made by people who are concerned about environmental deterioration. They maintain that higher output levels for the economy *as a whole* will cause a greater drain on natural resources and more pollution.

Accordingly, we examined the effects that the 2- and 3-child growth rates would have on GNP—the gross national product—which measures the total volume of goods and services produced. GNP is expected to more than double by the year 2000, whether the population grows rapidly or slowly.[2] This is the prospect implied by the projected increases in per capita income and the further growth of population resulting from the baby boom.

However, if families average three children in the future, GNP will grow far more than if they average two

**Separate statements by Commissioners Otis Dudley Duncan, with Paul B. Cornely, M.D. concurring (p. 153), John R. Meyer (p. 159) and James S. Rummonds (p. 167) appear on the indicated pages.*

children. In the year 2000, the difference in GNP resulting from different population assumptions amounts to as much as one-fourth of the total GNP today. Rapid population growth will cause more rapid growth in the size of the economy, and correspondingly greater demands on resources and the environment. People will not be better off economically with more rapid population growth—we have already seen that income per person is higher under the slower population growth assumption. Rather, increases in the number of people simply multiply the volume of goods and services produced and consumed. In the next chapter, we examine the meaning of these trends for resource consumption and deterioration of the environment.

Poverty

Income or output per capita is an average, and it conceals some gross disparities. We need to be concerned with these, especially at the lower end of the income scale—the people in poverty.

We have estimated the effects that slower population growth would have on poverty in the United States in the year 2000. We have found that the general improvement in average income associated with slower population growth would assist in reducing poverty, but would not eliminate it. This is not good enough.

There are today, by official estimate, 26 million Americans living in poverty conditions.[3] This is 13 percent of our population. Improvements in the average income of the population do something for these groups, but not enough. Their problem is that too many of them are not part of the system that generates and distributes income.

Over six million poor people are working adults who simply do not make enough money to meet even the minimal official income standard. Over three million of the poor are persons aged 14 to 64 who are sick or disabled, in school, or unable to find work. Nearly five million are over age 65, and over eight million are children. Finally, more than two million are female heads of family whose responsibilities at home keep them from taking jobs.

What this adds up to is that more than nine out of 10 poor people are excluded—because of age, incapacity, poor training, family responsibilities, fiscal disincentives, or discrimination in the labor market—from the system that produces and distributes income and the things income buys. Real improvements in their lot will be reflected in a changing distribution of income. But, while average income has risen dramatically and the number of poor has declined as a result, the relative distribution of income has changed little in the 25 years the Census Bureau has been measuring it.

In a country as wealthy and resourceful as ours, there is no excuse for permitting deprivation. For the working poor and those who cannot find work, the solution is to eliminate racial and sex discrimination in employment, and to improve education and training. Beyond this, we need a serious reexamination of the status of the aged. Old people are healthier and better educated than ever before. They are often forced to stop working far before the end of their productive lives, because of outright discrimination and outdated restrictions against older workers, and because of fiscal disincentives against work built into our social security laws and other pension arrangements.

Nevertheless, the country still has a number of people who cannot be helped by better access to the labor market. For these, the answer should be an increased public responsibility for maintaining a decent standard of living.

Measures to achieve an improved distribution of income should be beneficial demographically as well as socially. Evidence indicates that levels of childbearing—both wanted and unwanted—decline as income rises.

Labor Force Growth

Thirty-five million new workers will be seeking their first job in the decade of the 1970's.[4] That is seven million more than in the 1960's. This is one of the legacies of the baby boom. As that generation comes of age, swelling numbers of job applicants put an extra burden on full employment policy.

The pressure should be off in the 1980's. The number of new entrants to the labor force will probably be close to the figure for the 1970's, due to declining birthrates in the past decade. Once all the new entrants and women resuming work after their children are grown are balanced out against withdrawals through retirement and death, the labor force in 1990 should number some 114 million, or 28 million more than the 1970 figure.

What happens thereafter depends mainly on the number of births in the 1970's. If fertility should follow the 2-child projection, the number of people looking for their first job in the 1990's should be about the same as in the 1980's. However, if fertility follows the 3-child projection, the number of job seekers in the 1990's will jump 10 million, to a total of around 44 million; and by the year 2000, the total labor force will number some

136 million. Beyond 2000, the difference in labor force growth between the two projections becomes immense.

It seems clear that labor-force trends under the 3-child projection can be expected to generate greater pressure for increased production, employment, and consumption, and correspondingly greater problems associated with the social and environmental consequences of such increases. The 2-child projection does not imply that these problems can be avoided, only that they will be less pressing. It implies not only smaller numbers to be accommodated, but also a context in which the urgency of competing priorities will be muted.

We have seen that slower population growth causes a gradual increase in the percentage of old people and a decline in the percentage of youth—hence, a rising average age of the population. The same process also causes the labor force to age.

Concerns have been expressed that an older labor force will lack the energy, flexibility, and imagination of a younger one. Despite the absence of evidence for these concerns, their existence is further reason to support programs desirable on other grounds, such as the provision of continuing education to our labor force. Indeed, in light of the rapid changes occurring in all aspects of life, the idea that education should be completed by the age of 18, 22, or even 30, is clearly out of date.

Business

Will a slower rate of population growth hurt specific industries, particularly those which cater to young people? Does it threaten jobs?

While it is certainly true that there would be a faster increase in the sales of certain products, for example baby foods and milk, under conditions of higher population growth, it is also true that other products and services, for example convenience foods and airline travel, would be relatively favored by the faster rise in per capita income associated with slower population growth rates. More important, it does not appear, for several reasons, that a lower population growth rate will cause serious problems for any industry or its employees.[5]

First, regardless of the rate of population growth, total income, and hence demand, will rise.

Second, slower population growth will actually cause total as well as per capita income to be higher over the next 10 to 15 years than would a more rapid population growth rate. In other words, during the next 10 to 15 years total GNP in the 2-child projection would probably be slightly larger than in the 3-child case.

Third, it is important to note that under the 2-child family projection, there is no year in which there would be fewer births than there were in 1971. In other words, a gradual approach to population stabilization would not reduce demand from current levels for any industry we studied. (We studied the effect of the 2-child and 3-child population projections on demand for housing starts, mobile homes, domestic cars, imported cars, men's suits, frozen foods, power boats, credit, furniture and household equipment, food and beverages, beer, clothing and shoes, steel, dishwashers, railroad travel, and airline travel.)

Beyond the next 10 to 15 years, the adjustments businesses must make to changes in consumer tastes and technological developments should far exceed the problems of adjusting to a lower population growth rate. The loom tender in the diaper factory is hurt more by the competition from synthetic disposables than by the recent decline in births. Large fluctuations in birthrates will require larger adjustments by business than will small ones; still, we can have fluctuations around a 3-child as well as a 2-child growth rate. In declining communities, small businesses will not do as well economically as they would if there were more people around—some adjustments will be required. But other changes that are unpredictable today will require far more important adjustments by individuals, as well as by entire industries.

Past experience should lead to confidence that such adjustments can be made. Here is the Board Chairman of Atlantic-Richfield, testifying at our public hearing in New York:

> There is a habit of thinking in some segments of the business community, of course, that population increase is somehow essential to the maintenance of vigorous demand and economic growth, just as there is an instinctive reaction against any important new cost factors being added to the processes of production and distribution. But our economy has already, and in many ways, shown its tremendous adaptability to new social demands and necessities. I have not the slightest doubt that it can meet this new challenge.[6]

The Growth Mystique

In short, we find no convincing economic argu-

ment for continued national population growth. On the contrary, most of the plusses are on the side of slower growth. This finding is at variance with much opinion, especially in the business community and among many civic leaders. We have sought to find the reason for this seeming contradiction.

Periods of rapid population growth in this country have generally been periods of rapid economic expansion as well. It is not surprising, therefore, that we associate population growth with economic progress. However, the historical association of population growth with economic expansion would be an erroneous guide to the formulation of population policy for the future.

This connection reflects in large part the fact that periods of rapid economic expansion attracted immigrants to our shores and thus quickened population growth as a result. Additions to population through immigration are far more stimulating to economic growth than are additions by natural increase. This is because, while babies remain dependent for many years before beginning to contribute to output, many immigrants are of working age and thus become immediately productive. Immigration made a major contribution to rapid population growth up to World War I, but its effect since then has been much diminished. In the years 1861 to 1910, the average annual immigration rate per 1,000 Americans was 7.5; the rate for the period 1911 to 1970 dropped to 1.8. The rate for the recent period reflects a rise from the 1930's, when there was a net outflow of migrants, to the 1960's when the rate was 2.2.[7]

This answer may not satisfy the gas station owner, local food retailer, or banker, to whom it seems obvious that "more people" means more customers or more savings accounts. Once again, however, we need to examine the *kind* of growth that means more business, and its relationship to local economic expansion. The rapid local population growth that means more business results chiefly from more people moving in, not more people being born and raised. Adults moving in make ready customers and ready employees. They have grown up elsewhere, their education has been paid for elsewhere, and being young, they impose few of the demands of the dependent aged. Since mobile people are, on the average, better qualified than those who do not move, it is no surprise that they provide an extra boost to local establishments.

We have studied the effects of lower national population growth rates on the economic well-being of urban and rural areas within the nation. Is there reason to fear that the ills typical of areas of population decline today would become more serious or widespread if national population growth rates declined? We conclude that there is not; such fears are based on a mistaken belief that population decline causes economic decline. In reality, the chain of causation in distressed areas runs from (1) the decline of regional competitive capability to (2) unemployment to (3) net outmigration to (4) population loss.[8] Accordingly, there is little reason to suppose that local problems of unemployment or obsolescence of physical facilities would be more serious in a situation of zero or negative national population growth than they would be at any positive level of national population growth. In the future, as in the past, areas of relatively high unemployment will tend to be areas of relative population loss; but the relative population loss will be the consequence and not the cause of local unemployment.

The diminished burden of providing for dependents, and for the multiplication of facilities to keep up with expanding population, should make more of our national output available for many desirable purposes. new kinds of capital formation, including human resources investment; public expenditure involving qualitative improvement and modernization; and greater attention to environmental and amenity objectives. Thus, whatever the future problems of urban areas and regions may be, we should have more ample per capita resources to attack them in a situation with a lower rate of population growth than we would have with a higher rate.

Summary

We have looked for, and have not found, any convincing economic argument for continued national population growth. The health of our economy does not depend on it. The vitality of business does not depend on it. The welfare of the average person certainly does not depend on it.

In fact, the average person will be markedly better off in terms of traditional economic values if population growth follows the 2-child projection rather than the 3-child one. Slower growth will give us an older population, and this trend will require adjustments well within the ability of the nation to provide. Beyond this, however, we point out that the fruits of slower population growth will be denied to those most in need of them unless deliberate changes are made in distribution of income to those who lack it by reason of discrimination, incapacity, or age.

Chapter 5: Resources and the Environment

What are the likely future impacts of population growth on the demand for resources and on the environment in the United States? Here again, we have examined the consequences of the population growing according to the 2-child projection and the 3-child projection, and compared the results. For problems such as air pollution, where local concentrations are important, we have examined the implications of population growth in local areas as well as in the nation as a whole.[1]

For several resource and environmental topics, we have extended the analysis beyond the year 2000 to the year 2020; in so doing, we have identified some important effects that do not become particularly noticeable in the shorter period. Beyond the next 50 years, we do not know enough to make quantitative projections. Nonetheless, it is obvious that there are ultimate limits to growth. We live in a finite world. While its limits are unknown because technology keeps changing them, it is clear that the growth of population and the escalation of consumption must ultimately stop. The only questions are when, how, and at what level. The answers to these questions will largely be determined by the course of world population growth, including that of the United States.

Several general conclusions* emerge from our research:

1. Population growth is one of the major factors affecting the demand for resources and the deterioration of the environment in the United States. The further we look into the future, the more important population becomes.

2. From an environmental and resource point of view, there are no advantages from further growth of population beyond the level to which our past rapid growth has already committed us. Indeed, we would be considerably better off over the next 30 to 50 years if there were a prompt reduction in our population growth rate. This is especially true with regard to problems of water, agricultural land, and outdoor recreation.

3. While the nation can, if it has to, find ways to solve the problems growth creates, we will not like some of the solutions we will have to adopt. With continued growth, we commit ourselves to a particular set of problems: more rapid depletion of domestic and international resources, greater pressures on the environment, greater dependence on continued rapid technological development to solve these problems, and a more contrived and regulated society. So long as population growth continues, these problems will grow and will slowly, but irreversibly, force changes in our way of life. And there are further risks: Increasing numbers press us to adopt new technologies before we know what we are doing. The more of us there are, the greater is the temptation to introduce solutions before their side effects are known. With slower population growth leading to a stabilized population, we gain time to devise solutions, resources to implement them, and greater freedom of choice in deciding how we want to live in the future.

4. The American future cannot be isolated from what is happening in the rest of the world. There are serious problems right now in the distribution of resources, income, and wealth, among countries. World population growth is going to make these problems worse before they get better. The United States needs to undertake much greater efforts to understand these problems and develop international policies to deal with them.

*A separate statement by Commissioner Alan Cranston appears on page 150

How Population Affects Resources and the Environment

The pressure that this nation puts on resources and the environment during the next 30 to 50 years will depend on the size of the national population, the size of population in local areas, the amounts and types of goods and services the population consumes, and the ways in which these goods and services are produced, used, and disposed of. All these factors are important. Right now, because of our large population size and high economic productivity, the United States puts more pressure on resources and the environment than any other nation in the world.

We have attempted to separate these factors and estimate the impact of population on resources and the environment using a quantitative model which shows the demand for resources and the pollution levels associated with different rates of economic and population growth. The seriousness of the population-induced effects has then been assessed by evaluating the adequacy of resources to meet these requirements and the environmental impacts of pollution.

In discussing the economy, we indicated that under any set of economic projections, the total volume of goods and services produced in the United States —the gross national product—will be far larger than it is today. It is expected to be at least twice its present size by the year 2000, and in 50 years, with rapid population and economic growth, it could be seven times as large as it is now. Regardless of future population growth, the prospect is that increases in

output will cause tremendous increases in demand for resources and impact on the environment.

What happens to population growth will nevertheless make a big difference in the future size of the economy. In the year 2000, the difference in GNP resulting from the different population assumptions could amount to one-fourth of today's GNP. By the year 2020, this difference amounts to more than the total size of today's GNP.

In short, total GNP, which is the principal source of the demand for resources and the production of pollutants, will become much larger than it is now. But if population should grow at the 3-child rate, GNP will grow far more than it will at the 2-child rate.

Minerals

In our research, we examined the demand for 19 major nonfuel minerals: chromium, iron, nickel, potassium, cobalt, vanadium, magnesium, phosphorous, nitrogen, manganese, molybdenum, tungsten, aluminum, copper, lead, zinc, tin, titanium, and sulfur.

Resource consumption will rise more slowly if population grows more slowly. Our estimates indicate that the amount of minerals consumed in the year 2000 would average nine percent lower under the 2-child than under the 3-child population projection. The difference in annual consumption would be 17 percent in the year 2020, and would grow rapidly thereafter.

Population growth exerts an important effect on resource consumption compared with the effect of economic growth. Our research shows that in the year 2000, if GNP per capita were one percent less than projected, the consumption of most minerals would be 0.7 to 1.0 percent less; the consumption of four minerals—cobalt, magnesium, titanium, and sulfur—would be reduced relatively more. In the year 2000, if population were one percent less than projected, minerals consumption would be 0.5 to 0.7 percent less. The population effect, while substantial, is smaller because of an important offsetting effect. As we saw earlier, slower population growth induces higher output per person because of the favorable ratio of labor force to total population. This offsets somewhat the effect that smaller numbers have on the conservation of resources.

While there are clear resource savings from slower population growth, our research supports, with certain qualifications, the view that the United States would have no serious difficulty acquiring the supplies it needs for the next 50 years, even if the population were to grow at the 3-child rate. This is the prospect, even assuming, as we have done, that the resource demands of the rest of the world grow more rapidly than those of the United States, as has been the case in recent years. Although growing demand may pose some problems of adjustment, adequate supplies of all the minerals we studied can be achieved through tolerable price increases. Price increases will equalize supply and demand by stimulating exploration or imports (increased supply) and by stimulating recycling and the use of more plentiful substitutes (reduced demand). The earth's crust still contains immense quantities of lower grade minerals which can be called into production at levels of costs which we could afford to pay, even if the demands of the rest of the world should rise as projected and our population were to grow at the 3-child rate.

This expectation could be altered by several developments. First, prices could fail to anticipate impending shortages; that is, they might not rise long enough in advance to stimulate the changes necessary to avert shortages. Second, mining operations are heavy polluters, and mineral needs could conflict with environmental policy. Finally, and most serious, there are worldwide imbalances in access to resources. While the United States will remain among the "haves," relatively speaking, disparities between world regions may affect international power balances in ways that would involve us.

Energy

Energy makes the difference between poverty and affluence. The reason per capita income in the United States is so high is that the average American worker has at his command more energy, chiefly in the form of electricity, than any other worker in the world. With energy we refine aluminum, make rubber, shape steel, form new synthetic chemical compounds, propel automobiles, and heat our homes.

How much energy we have available depends on the availability of the necessary fuels and on our ability to convert the fuels to energy—the greatest advance in this regard was the development of inexpensive methods of electricity production. The technology of fuels acquisition and the technology of energy conversion are both critical. So is purchasing power—the ability to pay for domestic development of fuels or to import them. The original inhabitants of North America occupied a continent rich in energy fuels. But they neither knew how to get the fuels out of the ground nor how to convert them to energy. Some modern countries with advanced means of energy conversion lack their own

fuel supplies; they buy them from other countries.

The ability of the United States to meet its future energy needs will be determined chiefly by developments in technology—the technology of conversion and the technology of fuels acquisition. A major question will be whether we can find methods that are environmentally safe. Virtually every stage of energy use—fuel production, delivery, conversion, and consumption—has a significant environmental impact. For example, one-third of all coal is produced by strip mining, and the consequence is a scarred landscape and severe runoff into streams and rivers. Oil spills which contaminate the oceans and beaches may result from offshore drilling. Much airborne pollution comes from the use of such relatively dirty fuels as coal and oil. Some scientists are beginning to raise the possibility of thermal pollution resulting from concentrated use of energy in local areas. Nuclear power generation requires the disposal of radioactive atomic wastes. Because of these problems, the development of energy-production capacity could be impaired.

The increase in our energy needs will be immense under any projection, although not as large under the 2-child population projection as under the 3-child projection. The relative difference in energy demands under the different population projections is about the same as for minerals, and it becomes very large after the population with the lower rate of growth stabilizes. Whether population growth will strain fuel supplies, or cause serious environmental damage in the process of acquiring and using the necessary fuels, depends on future developments in technology.

With no major changes in technology, oil and gas supplies could become a problem for the United States by the year 2000—we would be importing more and paying higher prices; and supplies would certainly be a problem for some world regions. These problems could be averted if we found inexpensive means of using such potential sources as oil shale and tar sands, but using these sources is likely to have environmental consequences as serious as those from the strip-mining of coal. If we unlock the secrets of atomic fusion, we could have an environmentally clean way of generating electricity, with no fuel supply problem. The energy from converting the deuterium contained in 30 cubic kilometers of seawater would equal that of the earth's original supply of coal and petroleum.

Our review of the energy situation indicates that high priority ought to be given to research and development in clean sources of energy production. The faster population grows, the more urgent such breakthroughs become. We turn now to several areas where population growth dominates other considerations—where we cannot be hopeful about the ability of purchasing power and technical development to avert population problems.

Water

Water requirements already exceed available flow in the southwestern United States. Our research shows that growing population and economic activity will cause the area of water shortage to spread eastward and northward across the country in the decades ahead. Such deficits will spread faster if population growth follows the 3-child projection than if it follows the 2-child projection. This will occur despite large expenditures on water treatment, dams, and reservoirs during the next 50 years. Population growth will be more important than economic growth in causing these growing problems.

Our national abundance of water does not change this picture significantly. If water could be shipped across the country like oil, coal, or manufactured goods, there would be no problems of water shortage. But distances are so long and the amounts of water used so huge, that it would be prohibitively expensive to solve these regional problems by transfers of water from surplus to deficit areas. Nor is there scope for sufficiently large relocation of water users—people and industries—to regions where water is plentiful. An inexpensive method of taking the salt out of seawater could solve the problem, but such technology is not now available. Similarly, artificial control of rain is not advanced enough to be used to any significant extent. While little is known about the extent of groundwater reserves, most experts do not consider the mining of such reserves an adequate alternative.

On the other hand, there is wide scope for reducing use through rationing and the adoption of water-conserving technology. Even today, most water is used virtually free of cost or is distributed on a fee basis that provides no incentives for conservation; and free use of water bodies as waste dumping grounds is more the rule than the exception. If the cost of utilizing water for these purposes were raised to more appropriate levels, factories and power plants would install techniques of production that save water instead of wasting it; farmers would modify their irrigation practices or otherwise adjust by changing location or shifting to crops using less water; and households would eventually adjust by reducing lawns and shrubbery.

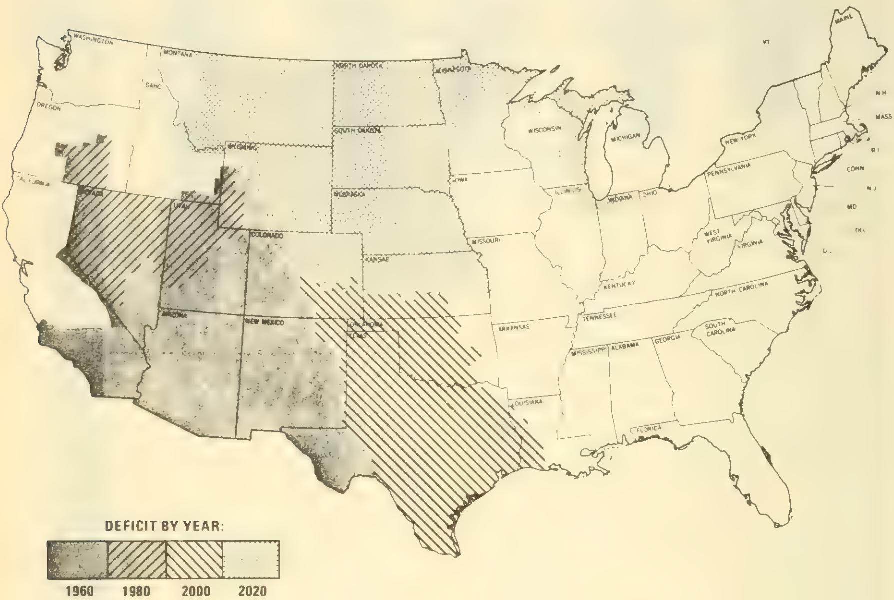
Figure 5.1 Regional Water Deficits: Billions of Gallons Per Day

Despite an abundance of water nationally, rapid population growth will cause the extent and severity of regional water deficits to spread more rapidly than they would with slower population growth. This is the case even assuming maximum development of water storage facilities and tertiary treatment of waste water.
Chart shows projected effects of growth at 2-child and 3-child rates.

Estimates assume rapid economic growth.

Source: Derived from Ronald G. Ridker, "Future Water Needs and Supplies, with a Note on Land Use" (prepared for the Commission, 1972).

Figure 5.2 Water Deficit Regions: 3-Child Family



Estimates assume rapid economic growth, maximum development of water storage facilities, and tertiary treatment

Alaska and Hawaii not shown Commission's data did not include these states

Source: Ronald G. Ridker, "Future Water Needs and Supplies, with a Note on Land Use" (prepared for the Commission, 1972).

Sooner or later we will have to deal with water as a scarce resource. The sooner this is done, the fewer water crises will emerge in the years ahead. However, doing this will not be easy technically or politically—most water supplies are run by local governments. And few will like the austerity created by the need to conserve on something as fundamental as water. The rate of national population growth will largely determine how rapidly we must accomplish these changes.

Outdoor Recreation

On a recent holiday weekend, Yosemite National Park had a population of 50,000 people, according to a Park source. Since then, the number of campsites has been reduced and traffic has been restricted in order to reduce noise and pollution. Still, visitors are put on notice that the water in the river is undrinkable. Yellowstone, too, has far more applications than can be accommodated in the available campsites. Even so, population densities in the non-wilderness areas of the Park sometimes exceed densities in the suburbs of Dallas.

More and more Americans have the time, the money, and the inclination to enjoy the outdoors. Production of truck campers and camping trailers shot up from 62 thousand in 1961 to over one-half million in 1971. With better roads and easier travel, national parks have in effect become city parks for the residents of nearby metropolitan areas. In the past 10 years, visitors to all national park facilities more than doubled, while the area of the parks increased by only one-fifth. There are many areas to enjoy and more to be developed, but the enjoyment will depend largely on how fast the population grows.

By the year 2000, incomes will nearly double and hours of leisure will rise. More and more people will be inclined to get away and will be able to do so. However, our research on some 24 outdoor recreation activities and the facilities for these activities indicates that population growing at the 3-child rate will exert great pressure on outdoor recreation resources—so great that, rather than "getting away" to the outdoors, people will be applying for admission to it.

In the face of rising congestion, many people will substitute organized sports, sightseeing, foreign travel, and artistic and cultural activities, if they so desire. Rising incomes and the increase in man-made facilities will make these alternatives possible. For many, these will be adequate alternatives, but for others they will not.

The prospects for recreation with the 2-child projection are much different for two reasons. First, the population will not be as large as that resulting from the 3-child rate. More important, the percentage of people in the young ages that make especially heavy use of outdoor recreation facilities will be smaller. As a consequence, we estimate that, in the year 2000, the demand for recreational facilities could be as much as 30 percent less under the 2-child than under the 3-child rate of growth.

Either way, recreation will differ from what it is now. The style of life may change with the lower rate of growth as well, shifting from more active to more sedentary pursuits. But in this case it would be voluntary, determined by the individual needs and preferences of an older population, not imposed by the desire to avoid overcrowding.

Agricultural Land and Food Prices

At a time when the federal government pays farmers to hold land out of production, it seems absurd to be looking forward to a scarcity of good agricultural land and rising food prices. Yet these are the prospects indicated by our analysis of what rapid United States population growth implies.

This picture emerges when we combine the requirements for feeding a rapidly growing population with a sound environmental policy which restricts the use of pesticides and chemical fertilizers. There are a number of reasons for believing that the nation will wish to limit application of these chemicals. But to do so will retard improvements in per acre productivity. This means that, to produce a given quantity of food, more acres must be brought into production. It is likely that, with such restrictions, all the high quality land will have been returned to production by the year 2000. Consequently, the task of feeding the more rapidly growing population would force us to bring an additional 50 million acres of relatively low-quality land into production.

This is an expensive undertaking requiring heavy investment in equipment, fertilizer, and manpower, for which farmers must be compensated. The result is that 50 years from now the population resulting from the 3-child average could find itself having to pay farm food prices some 40 to 50 percent higher than they would be otherwise. The needs of the population at the lower growth rate could be met with practically no price increase.

The larger population could avoid the price rise by shifting away from consumption of animal livestock

towards vegetables and synthetic meats. Perhaps it would shift to a closed system of agriculture—food from factories. One way or another, a solution can be found. The problem for a growing population is to survey the possible solutions and select the ones it dislikes least.

Pollution

As the gross national product goes up, so does the production of pollutants. An irony of economic measurement is that the value of goods and services represented by GNP includes the cost of producing the pollutants as well as expenditures for cleaning up afterward. We may fill our tank with gasoline, but due to engine inefficiency, some portion of that ends up in the atmosphere as air pollution. Such pollutants are not free—we had to pay good money to put them in the air. Yet the cost of putting them there is included in our principal measure of national economic well-being.

If we clean up the pollutants, the cost of the cleanup effort is also added to GNP. But many of the costs, such as poorer health and deteriorated surroundings, are never counted at all. It is an indictment of our ignorance and indifference toward what we do to the environment, that in our national economic accounts we count so few of the "bads," and that even when we do count them, we count them as "goods."

To understand the contribution of population to pollution, we have to distinguish two broad classes of pollutants. The first class includes the major products of combustion—carbon monoxide, carbon dioxide, oxides of nitrogen, oxides of sulfur, hydrocarbons, and particulates—and several measures of water pollution, including biochemical demand for oxygen and suspended and dissolved solids. The pollutants in this group, once produced, endure in the environment for a relatively short time—short enough so that long-term accumulations are not a problem. This group contains the more massive and commonly discussed pollutants, and enough information exists about them so that we can link them to economic activity and population.

The second class of pollutants includes those which endure longer—radiation and pesticides, plus a wide variety of ever-changing chemicals emitted by our high technology industries. Most such chemicals are emitted in small, often highly poisonous amounts. For many of these pollutants, future developments depend more heavily on changes in technology than on changes in population and economic growth. In any case, they are very difficult to link to population and economic growth in a simple and quantitative fashion. For this reason, the results we present here are for the first class of pollutants, although this does not minimize the environmental damage done by the others.

In the next 30 years, most of these pollutants can be eliminated by enforcing treatment standards for pollution emissions. Slower population and economic growth would help; but over this period, by far the biggest reduction in pollution can be achieved by a head-on attack. This is illustrated in Figure 5.3 for hydrocarbons—a major component of auto exhaust and other combustion. In this example, the treatment standard is the Environmental Protection Agency's 1975 standard for emissions into the air. Even if this standard were not met on schedule, it certainly will be met by the year 2000; indeed, by that time, we are likely to have much tighter standards.

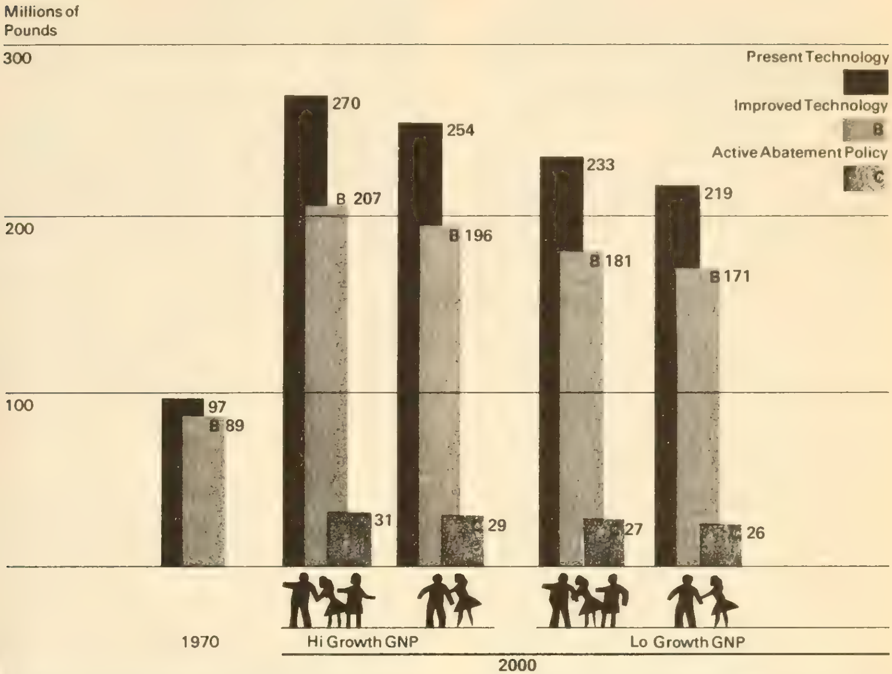
The relationships shown in Figure 5.3 hold generally for the other pollutants we examined. The reason for the spectacular results from enforcing standards is that we have imposed so little control in the past. The results do not assume any big new technological breakthroughs. It is just that we have only now begun to fight. Many of the required changes could be implemented today. Soap could be used instead of detergent; natural-colored paper could replace heavily bleached paper in many uses; returnable bottles could be used; the horsepower of auto engines could be reduced. It is not difficult to find answers when one begins to look.

Whatever we assume about future treatment policy, pollution emissions in the year 2000 would be less with the 2-child than with the 3-child rate of population growth—from five to 12 percent less, depending on the pollutant. If population were one percent less than projected in the year 2000, pollution emissions would be 0.3 to 0.6 percent less. If GNP per capita were one percent less than projected, emissions would be 0.2 to 0.9 percent less.

Once we achieve control over the emissions from each source, pollution will once again rise in response to economic and population growth. We can already see this process at work in rapidly growing parts of the country. At our Los Angeles public hearing, meteorologist James D. Edinger described the successful efforts in Los Angeles to control air pollution from stationary sources—power plants, heavy industry, home heating—and the beginnings of the program to control pollution from motor vehicles. But, he said, in recent years:

> . . . a close race has been run between increasing numbers of sources and decreasing emissions per source. But as emission levels per

Figure 5.3 Hydrocarbon Emissions



The generation and emission of hydrocarbon pollutants is shown under different assumptions about future population growth, economic growth, changes in technology, and pollution abatement policy.

The bars labeled A, shown for background purposes only, indicate the levels of hydrocarbon wastes that would be generated under present technology: These waste levels would be generated if there were no changes in technology between the 1967-1970 base period and the year 2000

The bars labeled B show actual emissions of hydrocarbon pollutants in 1970 and expected emissions in the year 2000, assuming no change in pollution abatement policy. The difference between A and B shows the extent to which the introduction of more efficient, less wasteful technology between now and the year 2000 is expected to reduce the generation and emission of pollutants below the levels generated if technology remained unchanged. Such changes in technology are likely to come anyway; they do not depend on public pressure to reduce harmful residuals.

The B bars show that, even with improved technology, pollution levels would be much higher in the year 2000 than they are now. These levels would, however, be somewhat lower if population grew at the 2-child rate rather than the 3-child rate, and if the economy grew at a slower rate rather than a more rapid rate (lo-growth GNP vs. hi-growth GNP).

The bars labeled C show hydrocarbon emissions in the year 2000 assuming an active pollution-abatement policy. The assumed policy is the Environmental Protection Agency's 1975 standard for emissions into the air. The changes in production and waste treatment processes induced by this policy would have a greater effect than would any of the other changes shown—in technology, population growth, or economic growth.

Source: Ronald G. Ridker, "The Economy, Resource Requirements, and Pollution Levels" (prepared for the Commission, 1972).

> source are trimmed lower and lower the effort required to achieve each new increment of improvement gets more and more difficult. The increase in the number of sources, on the other hand, is projected to rise steadily. If the race for acceptable air quality is to be won, the heroic emission control programs, present and anticipated in Los Angeles, must soon be joined by a leveling off, if not a reduction, in the number of sources.[2]

Our own research on air pollution indicates that such worries are well founded. The standard for concentrations of nitrogen oxides used by the Environmental Protection Agency is 100 micrograms per cubic meter. In 1970, the air in 36 urban areas had concentrations above this level. An active abatement policy would eliminate the problem in most areas. But if our projections of economic and population growth come anywhere close to the truth, Los Angeles and San Diego in the year 2000 will still have a problem. In Los Angeles, we estimate that even with an active abatement policy, concentrations of nitrogen oxides will still be at least 50 percent above standard, and probably well above that. In this region of the country, clearly something must give: the rate of population growth, the use of the internal combustion engine—especially for personal transport—or the standard itself.

As the case of air quality in Los Angeles illustrates, problems of environmental quality are often worse in metropolitan areas that are larger and in regions that are more densely populated. This is clearly true for air pollution (and associated respiratory disease), noise, traffic congestion, and time spent getting to work. Other factors are less clear. Our research shows that sewage and water treatment costs per person decline as city size increases to about 100,000; above that, engineering data suggest that costs should be the same for conventional facilities, but the actual observed costs appear to rise. If large cities have to change their sewage facilities, costs per person will be much higher. Similarly, solid waste disposal costs either follow a U-shaped curve or increase with city size and density. There is also evidence that large cities change local climate—wind, cloudiness, temperature, and precipitation; we really do not know whether or not such changes are bad. The inner city has all these environmental problems but to a heightened degree.

Yet the underlying cause of poor environmental quality in the larger urban centers may often not be size. Most of our largest centers are the old cities of the north; their problems may arise more from urban forms and transportation systems appropriate to an earlier era, old and uncoordinated facilities, multiple governmental jurisdictions, and the injustices that lead to inadequate financing and high proportions of minority groups and poor in central cities. In new cities as well as old, environmental quality suffers from inadequate pricing of public facilities and common property resources like space and waste disposal media, such as rivers and air. The historical evidence relating environmental quality to metropolitan size may not be applicable to the building of new cities and the refitting of older cities; indeed, many such problems would remain wherever people live.

The total volume of pollutants in the United States responds, as we have seen, to the size of the national economy, which in turn depends heavily on the size of the national population. People consume resources wherever they live. Whether in New York City or a small town in the midwest, people still drive an automobile made of steel using coal mined in West Virginia. In the process, the air in cities is fouled by smoke and the scenery and the streams of West Virginia are spoiled by strip mining. Wherever Americans live, they make huge demands on the nation's and the world's resources and environment.

Risks and Choices

As a nation, we have always faced choices and always will. What matters is the range of choice we have and the urgency with which the need to choose is thrust upon us. The evidence indicates that continued population growth narrows our choices and forces us to choose in haste.

From the standpoint of resources and the environment, the United States can cope with rapid population growth for the next 30 to 50 years. But doing so will become an increasingly unpleasant and risky business—unpleasant because "coping" with growth means adopting solutions we don't like; risky because it means adopting solutions before we understand them. Within the United States, the risks are ecological and social. And, there are risks which involve our relationship with the rest of the world.

We in this country are tampering with the ecosystem in many ways, the consequences of which we do not begin to understand. The crude methods used to estimate the effect of emissions on air quality and the damages and costs of urban pollution illustrate our ignorance all too well. Worse yet is our understanding of the second class of pollutants, bypassed in our analysis

precisely because we know so little about them. Because such pollutants endure longer, because they are highly poisonous in small doses, because new pollutants are continually being introduced, and because there are long time lags between emissions and the appearance of damages, we shall not quickly improve our knowledge in this area.

Radioactive wastes are an example. There will be more nuclear power plants if rapid population and economic growth occurs, but nuclear management and technology are changing so fast that there is no stable benchmark from which to estimate the amount of radioactive wastes likely to escape into the environment. We know that, once in the environment, such wastes can travel long distances through space and food chains, and we know the kinds of damage they can cause. But we do not know where they will come to rest, the extent of the damage, or when it will occur. Clearly, we need to know far more about how natural systems function when forced to absorb greater quantities of pollutants.

Beyond pollution, there are profound ecological impacts:[3] the simplification and destabilization of ecosystems associated with modern one-crop agriculture; the reduction in the variety of gene pools in our most important plants; the threat to the productivity of the sea through the filling-in of salt marshes; the unknown consequences of climate changes caused by man's activities; and many more.

Population growth is clearly not the sole culprit in ecological damage. To believe that it is, is to confuse how things are done with how many people are doing them. Much of the damage we do results from efforts to satisfy fairly trivial preferences—for unblemished fruit, detergents, rapidly accelerating cars, and bright colored paper products. We can and should cut back on frivolous and extravagant consumption that pollutes. The way things are done can, to a significant degree, be changed regardless of how many people are doing them. But the overall effect is a product of numbers times styles of life taken together. One multiplies the other to produce the total impact.

The real risk lies in the fact that increasing numbers press us to adopt new technologies before we know what we are doing. The more of us there are the greater is the temptation to introduce solutions before their side effects are known. It might be far better environmentally to postpone the introduction of nuclear power plants until the inherently cleaner fusion reactors are developed. When one pesticide or food additive is found to be dangerous to man, it is replaced with another about which we know less. We undertake the expenditure of billions on water treatment, without knowing whether the benefits outweigh the costs of other opportunities foregone. Slower population growth will not eliminate this situation, but it will reduce the urgency, the "crash program" character of much that we do. It will buy time for the development of sensible solutions.

We can cope with population growth for another half century if we have to; the question is whether we want to. We can cope with resource shortages—if we cannot mine a resource, we can import, design around it, find a substitute, or reduce consumption. Where water deficits threaten, we can choose between charging more for its use, transferring people and industry to other parts of the country, and constructing longer and larger canals. If pollution emissions cannot be tolerated, we can change production processes, improve treatment, separate polluters from their victims, treat the symptoms, or simply produce less of the commodity causing the pollution. Congestion during commuter hours can be handled by restricting the use of private cars, developing mass transit, and staggering work hours. Congestion at recreation sites can be handled by building additional facilities, improving management, encouraging substitutes such as foreign travel, and if necessary, by staggering vacations. Even land shortages for agriculture can be handled, given sufficient lead time, through farming the sea, changing our diet, developing synthetic foods, and so forth.

Such changes pose physical, technical, and managerial challenges that we can probably meet if we must. But in so doing, we shall pay a cost reckoned not in dollars but in our way of life.

Population growth forces upon us slow but irreversible changes in life style. Imbedded in our traditions as to what constitutes the American way of life is freedom from public regulation—virtually free use of water; access to uncongested, unregulated roadways; freedom to do as we please with what we own; freedom from permits, licenses, fees, red tape, and bureaucrats; and freedom to fish, swim, and camp where and when we will. Clearly, we do not live this way now. Maybe we never did. But everything is relative. The population of 2020 may look back with envy on what, from their vantage point, appears to be our relatively unfettered way of life.

Conservation of water resources, restrictions on pollution emissions, limitations on fertilizer and pesticides, preservation of wilderness areas, and protection of animal life threatened by man—all require public regulation. Rules must be set and enforced, complaints

heard and adjudicated. Granted, the more we can find means of relying on the price system, the easier will be the bureaucratic task. Indeed, we ought to be experimenting right now with ways of making price incentives induce appropriate use of the environment and resources. At present, most monetary incentives work the wrong way, inducing waste and pollution rather than the opposite.

But even if effluent charges and user fees became universal, they will have to be set administratively; emissions and use will have to be metered, and fees collected. It appears inevitable that a larger portion of our lives will be devoted to filling out forms, arguing with the computer or its representatives, appealing decisions, waiting for our case to be handled, finding ways to evade or to move ahead in line. In many small ways, everyday life will become more contrived.

Many such changes will have to occur no matter which population projection occurs. But the difference, small at first, would grow with time until, a half century from now, the two societies may appear qualitatively different.

Another price we pay for having to cope with continued population growth is the pressure to keep on postponing the solution of social problems. While growth continues, top priority will be given to finding the necessary resources, controlling pollutants, correcting the damages they have done, and building ever larger water canals, highways, and mass transit systems. A large and perhaps growing fraction of our physical and intellectual capital is directly or indirectly devoted to these tasks—to finding ways to cope with the problems that continued growth generates. From past experience, we can predict with a fair degree of confidence that such priorities will continue to subordinate efforts devoted to resolving fundamental social problems. When something must give because the system is becoming overloaded, it is unlikely to be the building of another dam.

The point is that continued population growth limits our options. In the case of the larger population, with less land per person and more people to accommodate, there are fewer alternatives, less room for diversity, less room for error. To cope with continued growth, technology *must* advance; lifestyles *must* change. Slower population growth offers us the difference between choice and necessity, between prudence and living dangerously.

The United States and the World

The research done for the Commission showed that the United States will greatly enlarge its demands on world resources, especially minerals and petroleum, over the decades ahead. We will be requiring substantially larger imports of many minerals, such as chromium, vanadium, cobalt, and nickel, for which domestic supplies are not available or are available only at substantially higher costs.

The demand of other countries for minerals, petroleum, and other resources will certainly also rise sharply over the coming decades. This will result from rapid increases in output per person in other industrialized countries and from the rapid modernization of agriculture and industry in developing countries. The rates of increase in production in other parts of the world are likely to be higher than those of the United States. Their rates of increase in demand for mineral supplies are likely to rise even more sharply, because they are at an earlier stage of the industrialization process and because the composition of their GNP includes proportionately more goods and fewer services than does that of the United States.

Taking into account the huge increases in population which are in prospect, it seems clear that demands for natural resources in other parts of the world will rise more rapidly than demands in the United States; thus, the share of the United States in the use of world resources will steadily decline. For example, projections made for the Commission indicate that over the next 50 years the share of the United States in the world's use of aluminum may decline from 37 percent in 1968 to as low as nine percent by the year 2020. In the same time period, the share of the United States of total world copper requirements may drop from 22 percent to five percent.

While all such figures necessarily reflect uncertain assumptions about production, income, and technology, nevertheless they indicate the extremely important extent to which the United States is inextricably involved in the development and use of resources on a worldwide scale.

Our research also demonstrates that environmental issues will have to be faced increasingly on an international basis over the years ahead. There are already conspicuous cases of environmental damage and risk which cannot be solved on a national basis. The continuing problem of petroleum pollution in the oceans is such a case. Neither the oceans nor the atmosphere can be successfully dealt with if one looks only at the territory within a nation's boundary. And many additional issues of international ecological significance will be increasingly important—such as the

effects of enormous increases in world use of pesticides and chemical fertilizers, the environmental impact of multi-national corporations, and many more.

The Commission has been deeply impressed by the unprecedented size and significance of the looming problems of resources and environment on a world scale. We see the need for much greater efforts than are underway now to analyze and understand these problems, and to develop international policies and programs to deal with them. We foresee potentially grave issues of clashing interests among nations and world regions, which could have very serious effects on the United States.

Therefore, we believe strongly that, in its own interest, the United States should work positively and constructively with other countries and international organizations in analyzing and solving problems related to natural resources and the environment in the world. We have made no special study of the detailed policies and programs which the United States should pursue for these purposes. We do now emphatically urge, however, that the nation join vigorously and cooperatively in solving problems of international trade, assistance to less-developed countries, and other pressing issues which will affect so sharply not only the future well-being of others in the world but the direct prospects for a sensible and respectable future for ourselves. We should not approach such problems in a spirit of charity or largesse. Our own future depends heavily on the evolution of a sensible international economic order, capable of dealing with natural resources and environmental conditions on a world scale.

Long-Term Strategic Planning

Our consideration of the problems and prospects involved in this country's long-term future convinces us that an important dimension of policy formation is being overlooked. This dimension involves the identification, study, and initiation of actions with respect to future problems that may require lead times of decades rather than years to resolve. There is a need for continuous monitoring and evaluation of the long-term implications of demographic changes, of future resource demands and supplies, of possible pollution overload situations, and of the underlying trends in technology and patterns of social behavior that influence these factors.

Once future problems are identified, there is a need to undertake the necessary research and development and to formulate the policies to resolve them. We need to study our social, political, and economic institutions with a view towards recommending modifications that will reduce the discrepancy between the private and the public interest. Practical procedures for utilizing the effluent charge approach to environmental quality management and for initiating a rational system of land-use planning are important cases in point. We need to develop technologies that conserve particularly scarce physical and environmental resources. While appropriate effluent charges will encourage private business to move in this direction, government sponsorship of "yardstick" research on industrial technologies is necessary, particularly when our concern is with the problems farther in the future than private business can afford to look.

While parts of these tasks are being performed by isolated agencies, coordination and analytical assessment on a broad level are lacking. Private business firms and most government agencies are of necessity too present-oriented or mission-oriented to serve these functions adequately; nor can they be left to *ad hoc* commissions such as this one. On the other hand, we do feel that some group should be assigned central responsibility for such functions. Such a body would serve as a "lobby for the future" to identify potential population, resource, and environmental problems well in advance of their occurrence; to establish priorities and sponsor technical and social research directed towards their resolution; and where necessary to formulate and recommend policies to that end.

Chapter 8: Population and Public Policy

We have reviewed population trends in the United States and examined their implications. Now we are ready to talk about the meaning of these trends for policy.

Four things stand out: First, the effects of our past rapid growth are going to be with us for a long time. Second, we have to make a choice about our future growth. Third, the choice involves nothing less than the quality of American life. And, fourth, slower population growth provides opportunities to improve the quality of life, but special efforts are required if the opportunities are to be well used.

A Legacy of Growth

Regardless of what happens to the birthrate from now on, our past growth commits us to substantial additional growth in the future. At a minimum, we will probably add 50 million more Americans by the end of the century, and the figure could easily be much higher than that.

We will be living for a long time with the consequences of the baby boom. Not long ago, that surge of births caused double sessions, school in trailers, and a teacher shortage. Now it is crowding the colleges and swelling the number of people looking for jobs. As these young people grow older, they will enter the ranks of producers as well as consumers, and they will eventually reenter dependency—the dependency of the aged.

We are going to have to plan for this. Swelling numbers of job applicants put an extra burden on full employment policy, if only because failure in this respect now affects so many more people than it did once. This will continue to be true for many years. People think the "baby boom" ended in the 1950's. Not so. That was only when it reached its peak. The last year when births exceed four million was 1964, only eight years ago.[1] In fact, today's eight-year-olds are just as numerous as 18-year-olds. So it is not too late to try to do better by the youngest of the baby-boom babies than we did by the oldest.

The baby boom is not over. The babies have merely grown older. It has become a boom in the teens and twenties. In a few decades, it will be turning into a retirement boom. During the second decade of the next century, 30 million people will turn 65, compared with 15 million who had their 65th birthday in the past 10 years.[2] Will the poverty of the aged be with us then? Census Bureau reports disclose that 25 percent of today's aged are in poverty, compared with eight percent of people in the young working ages of 22 to 45.[3] Thirty years from now, will we do better by the swelling numbers of aged than we do by those we have now? Will we develop alternatives to treating the elderly as castoffs? Not if we don't try. Not if we don't plan for it.

We may be through with the past, but the past is not done with us. Our demographic history shapes the future, even though it does not determine it. It sets forth needs as well as opportunities. It challenges us to get ready. While we cannot predict the future, much of it is foreseeable. For this much, at least, we should be prepared.

The Choice About Future Growth

We have to make a choice about our future growth. As a Commission, we have formed a definite judgment about the choice the nation should make. We have examined the effects that future growth alternatives are likely to have on our economy, society, government, resources, and environment, and we have found no convincing argument for continued national population growth. On the contrary, the plusses seem to be on the side of slowing growth and eventually stopping it altogether. Indeed, there might be no reason to fear a decline in population once we are past the period of growth that is in store.

Neither the health of our economy nor the welfare of individual businesses depend on continued population growth. In fact, the average person will be markedly better off in terms of traditional economic values if population growth slows down than if it resumes the pace of growth experienced in the recent past.

With regard to both resources and the environment, the evidence we have assembled shows that slower growth would conserve energy and mineral resources and would be a significant aid in averting problems in the areas of water supply, agricultural land supply, outdoor recreation resources, and environmental pollution.

Slower population growth can contribute to the nation's ability to solve its problems in these areas by providing an opportunity to devote resources to the quality of life rather than its quantity, and by "buying time"—that is, slowing the pace at which problems accumulate so as to provide opportunity for the development of orderly and democratic solutions.

For government, slower population growth offers potential benefits in the form of reduced pressures on

educational and other services; and, for the people, it enhances the potential for improved levels of service in these areas. We find no threat to national security from slower growth. While population growth is not by any means the sole cause of governmental problems, it magnifies them and makes their solution more difficult. Slower growth would lessen the increasing rate of strain on our federal system. To that extent, it would enhance the likelihood of achieving true justice and more ample well-being for all citizens even as it would preserve more individual freedom.

Each one of the impacts of population growth—on the economy, resources, the environment, government, or society at large—indicates the desirability, in the short run, for a slower rate of growth. And, when we consider these together, contemplate the ever-increasing problems involved in the long run, and recognize the long lead time required to arrest growth, we must conclude that continued population growth—beyond that to which we are already committed by the legacy of the baby boom—is definitely not in the interest of promoting the quality of life in the nation.

The Quality of American Life

We are concerned with population trends only as they impede or enhance the realization of those values and goals cherished in, by, and for American society.

What values? Whose goals? As a Commission, we do not set ourselves up as an arbiter of those fundamental questions. Over the decades ahead, the American people themselves will provide the answers, but we have had to judge proposals for action on population-related issues against their contribution to some version of the good life for this society and, for that matter, the world. What we have sought are measures that promise to move demographic trends in the right direction and, at the same time, have favorable direct effects on the quality of life.

We know that problems of quality exist from the variety of indicators that fall short of what is desirable and possible. There are inequalities in the opportunities for life itself evidenced by the high frequency of premature death and the lower life expectancy of the poor. There is a whole range of preventable illness such as the currently high and rising rate of venereal disease. There are a number of congenital deficiencies attributable to inadequate prenatal care and obstetrical services and, in some cases, to genetic origin. Not all such handicaps are preventable, but they occur at rates higher than if childbearing were confined to ages associated with low incidence and if genetic counseling were more widely available.

Innate human potential often has not been fully developed because of the inadequate quality of various educational, social, and environmental factors. Particularly with regard to our ethnic minorities and the female half of the population, there are large numbers of people occupying social roles that do not capitalize on their latent abilities and interest, or elicit a dedicated effort and commitment. There is hunger and malnutrition, particularly damaging to infants and young children, that should not be tolerated in the richest nation the world has ever known. Sensitive observers perceive in our population a certain frustration and alienation that appears to go beyond what is endemic in the human condition; the sources of these feelings should be explored and better understood.

And we can also identify and measure the limiting factors, the inequalities of opportunity, and the environmental hazards that give rise to such limitations in the quality of life—for example, inadequate distribution of and access to health, education, and welfare services; cultural and social constraints on human performance and development associated with race, ethnic origin, sex, and age; barriers to full economic and cultural participation; unequal access to environmental quality; and unequal exposure to environmental hazard.

There are many other problems of quality in American life. Thus, alongside the challenges of population growth and distribution is the challenge of population quality. The goal of all population policy must be to make better the life that is actually lived.

Opportunity and Choice

While slower population growth provides opportunities, it does not guarantee that they will be well used. It simply opens up a range of choices we would not have otherwise. Much depends on how wisely the choices are made and how well the opportunities are used. For example, slower population growth would enable us to provide a far better education for children at no increase in total costs. We want the opportunity presented by slower growth to be used this way, but we cannot guarantee that it will be. The wise use of opportunities such as this depends on public and private decisions yet to be made.

Slowing population growth can "buy time" for the solution of many problems; but, without the determined, long-range application of technical and

political skills, the opportunity will be lost. For example, our economic and political systems reward the exploitation of virgin resources and impose no costs on polluters. The technology exists for solving many of these problems. But proper application of this technology will require the recognition of public interests, the social inventiveness to discover institutional arrangements for channeling private interests without undue government regulation, and the political courage and skill needed to institute the necessary changes.

Slower population growth offers time in which to accomplish these things. But if all we do with breathing time is breathe, the value of the enterprise is lost.

Population change does not take place in a vacuum. Its consequences are produced through its joint action with technology, wealth, and the institutional structures of society. Hence, a study of the American future, insofar as it is influenced by population change, cannot ignore, indeed it must comment upon, the features of the society that make population growth troublesome or not.

Hence, while we are encouraged by the improvement in average income that will be yielded by slower population growth, we are concerned with the persistence of vast differences in the distribution of income, which has remained fixed now for a quarter of a century.

While we are encouraged by the relief that slower population growth offers in terms of pressure on resources and the environment, we are aware of the inadequacy of the nation's general approach to these problems.

We rely largely on private market forces for conducting the daily business of production and consumption. These work well in general and over the short run to reduce costs, husband resources, increase productivity, and provide a higher material standard of living for the individual. But the market mechanism has been ineffective in allocating the social and environmental costs of production and consumption, primarily because public policies and programs have not provided the proper signals nor required that such costs be borne by production and consumption activities. Nor has the market mechanism been able to provide socially acceptable incomes for people who, by virtue of age, incapacity, or injustice, are poorly equipped to participate in the market system for producing and distributing income.

Our economy's use of the earth's finite resources, and the accompanying pollution or deterioration of the quality of water, air, and natural beauty, has neglected some of the fundamental requirements for acceptable survival. Often the time horizon for both public and private decisions affecting the economy has been too short. It seems clear that market forces alone cannot be relied upon to achieve our social and environmental goals, for reasons that make exchange, though the main organizing principle, inadequate without appropriate institutional and legal underpinnings.[4]

In short, even if we achieve the stabilization of population, our economic, environmental, governmental, and social problems will still be with us unless by will and intelligence we develop policies to deal with the other sources of these problems. The fact that such policies have shown little conspicuous success in the past gives rise to the skepticism we have expressed above in our discussion of the relations between government and population growth.

The problem is not so much the impact of population on government as the adequacy of government to respond to the challenge of population and the host of issues that surround it. Long-term planning is necessary to deal with environmental and resource problems, but there are only beginning signs that government is motivated or organized to undertake it. A major commitment is required to bring minorities into the mainstream of American life, but the effort so far is inadequate. It is clear that the "real city" that comprises the metropolis requires a real government to manage its affairs; but the nation is still trying to manage the affairs of complex, interconnected, metropolitan communities with fragmented institutional structures inherited from the 18th century.

Population, then, is clearly not the whole problem. But it is clearly part of the problem, and it is the part given us as the special responsibility of this Commission. How policy in this area should be shaped depends on how we define the objectives of policy in respect to population.

Policy Goals

Ideally, we wish to develop recommendations worthwhile in themselves, which at the same time, speak to population issues. These recommendations are consistent with American ethical values in that they aim to enhance individual freedom while simultaneously promoting the common good. It is important to reiterate that our policy recommendations embody goals either intrinsically desirable or worthwhile for reasons other than demographic objectives.

Moreover, some of the policies we recommend are

irreversible in a democratic society, in the sense that freedoms once introduced cannot be rescinded lightly. This irreversibility characterizes several of the important policies recommended by this Commission. We are not really certain of the demographic impact of some of the changes implied by our recommendations. One or two could conceivably increase the birthrate by indirectly subsidizing the bearing of children. The rest may depress the birthrate below the level of replacement. We are not concerned with this latter contingency because, if sometime in the future the nation wishes to increase its population growth, there are many possible ways to try this; a nation's growth should not depend on the ignorance and misfortune of its citizenry. In any event, it is naive to expect that we can fine-tune such trends.

In the broadest sense, the goals of the population policies we recommend aim at creating social conditions wherein the desired values of individuals, families, and communities can be realized; equalizing social and economic opportunities for women and members of disadvantaged minorities; and enhancing the potential foı improving the quality of life.

At the educational level, we wish to increase public awareness and understanding of the implications of population change and simultaneously further our knowledge of the causes and consequences of population change.

In regard to childbearing and child-rearing, the goals of our recommendations are to: (1) maximize information and knowledge about human reproduction and its implications for the family; (2) improve the quality of the setting in which children are raised; (3) neutralize insofar as it is practicable and consistent with other values those legal, social, and institutional pressures that historically have been mainly pronatalist in character; and (4) enable individuals to avoid unwanted childbearing, thereby enhancing their ability to realize their preferences. These particular policies are aimed at facilitating the social, economic, and legal conditions within our society which increase ethical responsibility and the opportunity for unbiased choice in human reproduction and child-rearing. At the same time, by enhancing the individual's opportunity to make a real choice between having few children and having many, between parenthood and childlessness, and between marriage and the single state, these policies together will undoubtedly slow our rate of population growth and accelerate the advent of population stabilization.

In connection with the geographic distribution of population, our objectives are to ease and guide the process of population movement, to facilitate planning for the accommodation of movements, and to increase the freedom of choice in residential locations.

To these ends, therefore, we offer our recommendations in the belief that the American people, collectively and individually, should confront the issues of population growth and reach deliberate informed decisions about the family's and society's size as they affect the achievement of personal and national values.

Chapter 12: Population Stabilization

The Commission's Perspective

Soon after the Commission's first meeting in June 1970, it became evident that the question of population stabilization would be a principal issue in its deliberations. A population has stabilized when the number of births has come into balance with the number of deaths, with the result that, the effects of immigration aside, the size of the population remains relatively constant. We recognize that stabilization will only be possible on an average over a period of time, as the annual numbers of births and deaths fluctuate. The Commission further recognizes that to attain a stabilized population would take a number of decades, primarily because such a high proportion of our population today is now entering the ages of marriage and reproduction.

As our work proceeded and we received the results of studies comparing the likely effects of continued growth with the effects of stabilization, it became increasingly evident that no substantial benefits would result from continued growth of the nation's population. This is one of the basic conclusions we have drawn from our inquiry. From the accumulated evidence, we further concluded that the stabilization of our population would contribute significantly to the nation's ability to solve its problems. It was evident that moving toward stabilization would provide an opportunity to devote resources to problems and needs relating to the quality of life rather than its quantity. Stabilization would "buy time" by slowing the pace at which growth-related problems accumulate and enhancing opportunities for the orderly and democratic working out of solutions.

The Commission recognizes that the demographic implications of most of our recommended policies concerning childbearing are quite consistent with a goal of population stabilization. In this sense, achievement of population stabilization would be primarily the result of measures aimed at creating conditions in which individuals, regardless of sex, age, or minority status, can exercise genuine free choice. This means that we must strive to eliminate those social barriers, laws, and cultural pressures that interfere with the exercise of free choice and that governmental programs in the future must be sensitized to demographic effects.*

Recognizing that our population cannot grow indefinitely, and appreciating the advantages of moving now toward the stabilization of population, the Commission recommends that the nation welcome and plan for a stabilized population.

**A separate statement by Commissioner Paul B. Cornely, M.D. appears on page 149.*

There remain a number of questions which must be answered as the nation follows a course toward population stabilization. How can stabilization be reached? Is there any particular size at which the population should level off, and when should that occur? What "costs" would be imposed by the various paths to stabilization, and what costs are worth paying?

Criteria for Paths to Stabilization

An important group in our society, composed predominantly of young people, has been much concerned about population growth in recent years. Their concern emerged quite rapidly as the mounting pollution problem received widespread attention, and their goal became "zero population growth." By this, they meant in fact stabilization—bringing births into balance with deaths. To attain their objective, they called for the 2-child family. They recognize, of course, that many people do not marry and that some who do marry either are not able to have or do not want to have children, permitting wide latitude in family size and attainment of the 2-child average.

Some called for zero growth immediately. But this would not be possible without considerable disruption to society. While there are a variety of paths to ultimate stabilization, none of the feasible paths would reach it immediately. Our past rapid growth has given us so many young couples that, even if they merely replaced themselves, the number of births would still rise for several years before leveling off. To produce the number of births consistent with immediate zero growth, they would have to limit their childbearing to an average of only about one child. In a few years, there would be only half as many children as there are now. This would have disruptive effects on the school system and subsequently on the number of persons entering the labor force. Thereafter, a constant total population could be maintained only if this small generation in turn had two children and their grandchildren had nearly three children on the average. And then the process would again have to reverse, so that the overall effect for many years would be that of an accordion-like continuous expansion and contraction.[1]

From considerations such as this, we can begin to develop criteria for paths toward population stabilization.[2] It is highly desirable to avoid another baby boom.

Births, which averaged 3.0 million annually in the early 1920's, fell to a 2.4 million average in the 1930's, rose to a 4.2 million average in the late 1950's and early 1960's, and fell to 3.6 million in 1971.[3] These boom and bust cycles have caused disruption in elementary and high schools and subsequently in the colleges and in the labor market. And the damage to the long-run career aspirations of the baby-boom generation is only beginning to be felt.

The assimilation of the baby-boom generation has been called "population peristalsis," comparing it to the process in which a python digests a pig. As it moves along the digestive tract, the pig makes a big bulge in the python. While the imagery suggests the appearance of the baby-boom generation as it moves up the age scale and through the phases of the life cycle, there is reason to believe that the python has an easier time with the pig than our nation is having providing training, jobs, and opportunity for the generation of the baby boom.

Thus, we would prefer that the path to stabilization involve a minimum of fluctuations from period to period in the number of births. For the near future, these considerations recommend a course toward population stabilization which would reduce the echo expected from the baby-boom generation as it moves through the childbearing ages and bears children of its own.

Our evidence also indicates that it would be preferable for the population to stabilize at a lower rather than a higher level. Our population will continue to grow for decades more before stabilizing, even if those now entering the ages of reproduction merely replace themselves. The population will grow as the very large groups now eight to 25 years of age—the products of the postwar baby boom—grow older and succeed their less numerous predecessors. How much growth there will be depends on the oncoming generations of young parents.

Some moderate changes in patterns of marriage and childbearing are necessary for any move toward stabilization. There are obvious advantages to a path which minimizes the change required and provides a reasonable amount of time for such change to occur.

Population stabilization under modern conditions of mortality means that, on the average, each pair of adults will give birth to two children. This average can be achieved in many ways. For example, it can be achieved by varying combinations of nonmarriage or childlessness coexisting in a population with substantial percentages of couples who have more than two children. On several grounds, it is desirable that stabilization develop in a way which encourages variety and choice rather than uniformity.

We prefer, then, a course toward population stabilization which minimizes fluctuations in the number of births; minimizes further growth of population; minimizes the change required in reproductive habits and provides adequate time for such changes to be adopted; and maximizes variety and choice in life styles, while minimizing pressures for conformity.

An Illustration of an Optimal Path

Our research indicates that there are some paths to stabilization that are clearly preferable. These offer less additional population growth, involve negligible fluctuations in births, provide for a wide range of family sizes within the population, and exact moderate "costs"—that is, changes in marriage and childbearing habits, which are in the same direction as current trends.

A course such as the following satisfies these criteria quite well.[4] (The calculations exclude immigration; the demographic role of immigration is reviewed in the next chapter.)

In this illustration, childbearing would decline to a replacement level in 20 years. This would result if: (1) the proportion of women becoming mothers declined from 88 to 80 percent; (2) the proportion of parents with three or more children declined from 50 to 41 percent; and (3) the proportion of parents with one or two children rose from 50 to 59 percent. Also in this illustration, the average age of mothers when their first child is born would rise by two years, and the average interval between births would rise by less than six months. The results of these changes would be that the United States population would gradually grow until it stabilizes, in approximately 50 years, at a level of 278 million (plus the contribution from the net inflow of immigrants). Periodic fluctuations in the number of births would be negligible.

The size of the population in the year 2000 will depend both on how fast future births occur as well as on the ultimate number of children people have over a lifetime. Over the next 10 to 15 years especially, we must expect a large number of births from the increasing numbers of potential parents, unless these young people offset the effect of their numbers by waiting somewhat before having their children. Postponement and stretching-out of childbearing, accompanied by a gradual decline in the number of children that people have over a lifetime, can effectively reduce

the growth we shall otherwise experience.

Beyond this, there are persuasive health and personal reasons for encouraging postponement of childbearing and better spacing of births. Infants of teenage mothers are subject to higher risks of premature birth, infant death, and lifetime physical and mental disability than children of mothers in their twenties.[5] If the 17 percent of all births occurring to teenage mothers were postponed to later ages, we would see a distinct improvement in the survival, health, and ability of these children.

It is obvious that the population cannot be fine-tuned to conform to any specific path. The changes might occur sooner or later than in this illustration. If they took place over 30 years instead of 20 we should expect nine million more people in the ultimate stabilized population—or 287 million rather than 278 million. Or if the average age at childbearing rose only one year instead of two, we would end up with 10 million more people than otherwise.

On the other hand, suppose we drifted toward a replacement level of fertility in 50 years instead of 20, and none of the other factors changed. In that case, the population would stabilize at 330 million. In other words, following this route would result in 50 million more Americans than the one illustrated above.

The Likelihood of Population Stabilization

Many developments—some old and some recent—enhance the likelihood that something close to an optimal path can be realized, especially if the Commission's recommendations bearing on population growth are adopted quickly.

1. The trend of average family size has been downward—from seven or eight children per family in colonial times to less than three children in recent years—interrupted, however, by the baby boom.

2. The birthrate has declined over the past decade and showed an unexpected further decline in 1971.

3. The increasing employment of women, and the movement to expand women's options as to occupational and family roles and life styles, promise to increase alternatives to the conventional role of wife-homemaker-mother.

4. Concern over the effects of population growth has been mounting. Two-thirds of the general public interviewed in the Commission's survey in 1971 felt that the growth of the United States population is a serious problem. Half or more expressed concern over the impact of population growth on the use of natural resources, on air and water pollution, and on social unrest and dissatisfaction.[6]

5. Youthful marriage is becoming less common than it was a few years ago. While 20 percent of women now in their thirties married before age 18, only 13 percent of the young women are doing so now.[7] It remains to be seen whether this represents a postponement of marriage or a reversal of the trend toward nearly universal marriage.

6. The family-size preferences of young people now entering the childbearing ages are significantly lower than the preferences reported by their elders at the same stage in life.

7. The technical quality of contraceptives has increased greatly in the past 10 years, although irregular and ineffective use still results in many unplanned and unwanted births.

8. The legalization of abortion in a few states has resulted in major increases in the number of legal abortions. The evidence so far indicates that legalized abortion is being used by many women who would otherwise have had to resort to illegal and unsafe abortions. The magnitude of its effect on the birthrate is not yet clear.[8]

9. The experience of many other countries indicates the feasibility of sustained replacement levels of reproduction.[9] Within the past half century, Japan, England and Wales, France, Denmark, Norway, West Germany, Hungary, Sweden, and Switzerland have all experienced periods of replacement or near-replacement fertility lasting a decade or more. Additional countries have had shorter periods at or near replacement levels. While much of this experience occurred during the Depression of the 1930's, much of it also occurred since then. Furthermore, during that period, contraceptive technology was primitive compared to what is available today.

On the basis of these facts, the nation might ask, "why worry," and decide to wait and see what happens. Our judgment is that we should not wait. Acting now, we encourage a desirable trend. Acting later, we may find ourselves in a position of trying to reverse an undesirable trend. We should take advantage of the opportunity the moment presents rather than wait for what the unknown future holds.

The potential for a repeat of the baby boom is still here. In 1975, there will be six million more people in the prime childbearing ages of 20 to 29 than there were in 1970. By 1985, the figure will have jumped still another five million. Unless we achieve some postponement of childbearing or reduction in average family size,

this is going to mean substantial further increases in the number of births.[10]

Furthermore, although we discern many favorable elements in recent trends, there are also unfavorable elements which threaten the achievement of stabilization.

1. For historical reasons which no longer apply, this nation has an ideological addiction to growth.

2. Our social institutions, including many of our laws, often exert a pronatalist effect, even if inadvertent.[11] This includes the images of family life and women's roles projected in television programs; the child-saves-marriage theme in women's magazines;[12] the restrictions on the availability of contraception, sex education, and abortion; and many others.

3. There is an unsatisfactory level of understanding of the role of sex in human life and of the reproductive process and its control.

4. While the white middle-class majority bears the primary numerical responsibility for population growth, it is also true that the failure of our society to bring racial minorities and the poor into the mainstream of American life has impaired their ability to implement small-family goals.

5. If it should happen that, in the next few years, our rate of reproduction falls to replacement levels or below, we could experience a strong counterreaction. In the United States in the 1930's, and in several foreign countries, the response to subreplacement fertility has been a cry of anxiety over the national prosperity, security, and virility. Individual countries have found it hard to come to terms with replacement-level fertility rates.[13] About 40 years ago during the Depression, there was great concern about "race suicide" when birthrates fell in Western Europe and in this country. Indeed, an admonition against unwarranted countermeasures was issued in 1938 by the Committee on Population Problems of the National Resources Committee: ". . .there is no occasion for hysteria. . . . There is no reason for the hasty adoption of any measures designed to stimulate population growth in this country."[14] Today, several countries approaching stabilization have expressed concerns about possible future labor shortages. The growth ethic seems to be so imprinted in human consciousness that it takes a deliberate effort of rationality and will to overcome it, but that effort is now desirable.

One purpose of this report and the programs it recommends is to prepare the American people to welcome a replacement level of reproduction and some periods of reproduction below replacement. The nation must face the fact that achieving population stabilization sooner rather than later would require a period of time during which annual fertility was below replacement. During the transition to stabilization, the postponement of childbearing would result in annual fertility rates dropping below replacement, even though, over a lifetime, the childbearing of the parents would reach a replacement level.

In the long-run future, we should understand that a stabilized population means an *average* of zero growth, and there would be times when the size of the population declines. Indeed, zero growth can only be achieved realistically with fluctuations in both directions. We should prepare ourselves not to react with alarm, as some other countries have done recently, when the distant possibility of population decline appears.

Compilation of Recommendations

Population Education

In view of the important role that education can play in developing an understanding of the causes and consequences of population growth and distribution, the Commission recommends enactment of a Population Education Act to assist school systems in establishing well-planned population education programs so that present and future generations will be better prepared to meet the challenges arising from population change.

To implement such a program, the Commission recommends that federal funds be appropriated for teacher training, for curriculum development and materials preparation, for research and evaluation, for the support of model programs, and for assisting state departments of education to develop competence and leadership in population education.

Sex Education

Recognizing the importance of human sexuality, the Commission recommends that sex education be available to all, and that it be presented in a responsible manner through community organizations, the media, and especially the schools.

Child Care

The Commission recommends that both public and private forces join together to assure that adequate child-care services, including health, nutritional, and educational components, are available to families who wish to make use of them.

Because child-care programs represent a major innovation in child-rearing in this country, we recommend that continuing research and evaluation be undertaken to determine the benefits and costs to children, parents, and the public of alternative child-care arrangements.

Children Born Out of Wedlock

The Commission recommends that all children, regardless of the circumstances of their birth, be accorded fair and equal status socially, morally, and legally.

The Commission urges research and study by the American Bar Association, the American Law Institute, and other interested groups leading to revision of those laws and practices which result in discrimination against out-of-wedlock children. Our end objective should be to accord fair and equal treatment to all children.

Adoption

The Commission recommends changes in attitudes and practices to encourage adoption thereby benefiting children, prospective parents, and society.

To implement this goal, the Commission recommends:

Further subsidization of families qualified to adopt, but unable to assume the full financial cost of a child's care.

A review of current laws, practices, procedures, and regulations which govern the adoptive process.

Equal Rights for Women

The Commission recommends that the Congress and the states approve the proposed Equal Rights Amendment and that federal, state, and local governments undertake positive programs to ensure freedom from discrimination based on sex.

Contraception and the Law

The Commission recommends that: (1) states eliminate existing legal inhibitions and restrictions on access to contraceptive information, procedures, and supplies; and (2) states develop statutes affirming the desirability that all persons have ready and practicable access to contraceptive information, procedures, and supplies.

Contraception and Minors

The Commission recommends that states adopt affirmative legislation which will permit minors to receive contraceptive and prophylactic information and services in appropriate settings sensitive to their needs and concerns.

> *To implement this policy, the Commission urges that organizations, such as the Council on State Governments, the American Law Institute, and the American Bar Association, formulate appropriate model statutes.*

Voluntary Sterilization

In order to permit freedom of choice, the Commission recommends that all administrative restrictions on access to voluntary contraceptive sterilization be eliminated so that the decision be made solely by physician and patient.

> *To implement this policy, we recommend that national hospital and medical associations, and their state chapters, promote the removal of existing restrictions.*

Abortion

With the admonition that abortion not be considered a primary means of fertility control, the Commission recommends that present state laws restricting abortion be liberalized along the lines of the New York statute, such abortion to be performed on request by duly licensed physicians under conditions of medical safety.

> *In carrying out this policy, the Commission recommends:*
>
> *That federal, state, and local governments make funds available to support abortion services in states with liberalized statutes.*
>
> *That abortion be specifically included in comprehensive health insurance benefits, both public and private.*

Methods of Fertility Control

The Commission recommends that this nation give the highest priority to research in reproductive biology and to the search for improved methods by which individuals can control their own fertility.

> *In order to carry out this research, the Commission recommends that the full $93 million authorized for this purpose in fiscal year 1973 be appropriated and allocated; that federal expenditures for these purposes rise to a minimum of $150 million by 1975; and that private organizations continue and expand their work in this field.*

Fertility-Related Health Services

The Commission recommends a national policy and voluntary program to reduce unwanted fertility, to improve the outcome of pregnancy, and to improve the health of children.

> *In order to carry out such a program, public and private health financing mechanisms should begin paying the full cost of all health services related to*

fertility, including contraceptive, prenatal, delivery, and postpartum services; pediatric care for the first year of life; voluntary sterilization; safe termination of unwanted pregnancy; and medical treatment of infertility.

Personnel Training and Delivery of Services

We recommend creation of programs to (1) train doctors, nurses, and paraprofessionals, including indigenous personnel, in the provision of all fertility-related health services; (2) develop new patterns for the utilization of professional and paraprofessional personnel; and (3) evaluate improved methods of organizing the delivery of these services.

Family Planning Services

The Commission recommends: (1) new legislation extending the current family planning project grant program for five years beyond fiscal year 1973 and providing additional authorizations to reach a federal funding level of $225 million in fiscal year 1973, $275 million in fiscal year 1974, $325 million in fiscal year 1975, and $400 million thereafter; (2) extension of the family planning project grant authority of Title V of the Social Security Act beyond 1972, and maintenance of the level of funding at approximately $30 million annually; and (3) maintenance of the Title II OEO program at current levels of authorization.

Services for Teenagers

Toward the goal of reducing unwanted pregnancies and childbearing among the young, the Commission recommends that birth control information and services be made available to teenagers in appropriate facilities sensitive to their needs and concerns.

The Commission recommends the development and implementation of an adequately financed program to develop appropriate family planning materials, to conduct training courses for teachers and school administrators, and to assist states and local communities in integrating information about family planning into school courses such as hygiene and sex education.

Population Stabilization

Recognizing that our population cannot grow indefinitely, and appreciating the advantages of moving now toward the stabilization of population, the Commission recommends that the nation welcome and plan for a stabilized population.

Illegal Aliens

The Commission recommends that Congress immediately consider the serious situation of illegal immigration and pass legislation which will impose civil and criminal sanctions on employers of illegal border-crossers or aliens in an immigration status in which employment is not authorized.

To implement this policy, the Commission recommends provision of increased and strengthened resources consistent with an effective enforcement program in appropriate agencies.

Immigration

The Commission recommends that immigration levels not be increased and that immigration policy be reviewed periodically to reflect demographic conditions and considerations.

To implement this policy, the Commission recommends that Congress require the Bureau of the Census, in coordination with the Immigration and Naturalization Service, to report biennially to the Congress on the impact of immigration on the nation's demographic situation.

National Distribution and Migration Policies

The Commission recommends that:

The federal government develop a set of national population distribution guidelines to serve as a framework for regional, state, and local plans and development.

Regional, state, and metropolitan-wide governmental authorities take the initiative, in cooperation with local governments, to conduct needed comprehensive planning and action programs to achieve a higher quality of urban development.

The process of population movement be eased and guided in order to improve access or opportunities now restricted by physical remoteness, immobility, and inadequate skills, information, and experience.

Action be taken to increase freedom in choice of residential location through the elimination of current patterns of racial and economic segregation and their attendant injustices.

Guiding Urban Expansion

To anticipate and guide future urban growth, the Commission recommends comprehensive land-use and public-facility planning on an overall metropolitan and regional scale.

The Commission recommends that governments exercise greater control over land-use planning and development.

Racial Minorities and the Poor

To help dissolve the territorial basis of racial polarization, the Commission recommends vigorous and concerted steps to promote free choice of housing within metropolitan areas.

To remove the occupational sources of racial polarization, the Commission recommends the development of more extensive human capital programs to equip black and other deprived minorities for fuller participation in economic life.

To reduce restrictions on the entry of low- and moderate-income people to the suburbs, the Commission recommends that federal and state governments ensure provision of more suburban housing for low- and moderate-income families.

To promote a more racially and economically integrated society, the Commission recommends that actions be taken to reduce the dependence of local jurisdictions on locally collected property taxes.

Depressed Rural Areas

To improve the quality and mobility potential of individuals, the Commission recommends that future programs for declining and chronically depressed rural areas emphasize human resource development.

To enhance the effectiveness of migration, the Commission recommends that programs be developed to provide worker-relocation counseling and assistance to

95-852 O - 73 - 39

enable an individual to relocate with a minimum of risk and disruption.

To promote the expansion of job opportunities in urban places located within or near declining areas and having a demonstrated potential for future growth, the Commission recommends the development of a growth center strategy.

Institutional Responses

The Commission recommends the establishment of state or regional development corporations which would have the responsibility and the necessary powers to implement comprehensive development plans either as a developer itself or as a catalyst for private development.

Population Statistics and Research

The Commission recommends that the federal government move promptly and boldly to strengthen the basic statistics and research upon which all sound demographic, social, and economic policy must ultimately depend, by implementing the following specific improvements in these programs.

Vital Statistics Data

The Commission recommends that the National Center for Health Statistics improve the timeliness and the quality of data collected with respect to birth, death, marriage, and divorce.

Enumeration of Special Groups

The Commission recommends that the federal government support, even more strongly, the Census Bureau's efforts to improve the completeness of our census enumeration, especially of minority groups, ghetto populations, and all unattached adults, especially males, who are the least well counted.

International Migration

The Commission recommends that a task force be designated under the leadership of the Office of Management and Budget to devise a program for the development of comprehensive immigration and emigration statistics, and to recommend ways in which the records of the periodic alien registrations should be processed to provide information on the distribution and characteristics of aliens in the United States.

The Current Population Survey

The Commission recommends that the government provide substantial additional support to the Current Population Survey to improve the area identification of those interviewed and to permit special studies, utilizing enlarged samples, of demographic trends in special groups of the population.

Statistical Reporting of Family Planning Services

The Commission recommends the rapid development of comprehensive statistics on family planning services.

National Survey of Family Growth

The Commission recommends program support and continued adequate financial support for the Family Growth Survey as almost the first condition for evaluating the effectiveness of national population policies and programs.

Distribution of Government Data

The Commission recommends that the various statistical agencies seek to maximize the public usefulness of the basic data by making identity-free tapes available to responsible research agencies.

Mid-Decade Census

The Commission recommends that the decennial census be supplemented by a mid-decade census of the population.

Statistical Use of Administrative Records

The Commission recommends that the government give high priority to studying the ways in which federal administrative records, notably those of the Internal Revenue Service and Social Security Administration, could be made more useful for developing statistical estimates of local population and internal migration.

Intercensal Population Estimates

The Commission recommends that the government provide increased funding, higher priority, and accelerated development for all phases of the Census Bureau's program for developing improved intercensal population estimates for states and local areas.

Social and Behavioral Research

The Commission recommends that substantial increases in federal funds be made available for social and behavioral research related to population growth and distribution, and for the support of nongovernmental population research centers.

Research Program in Population Distribution

The Commission recommends that a research program in population distribution be established, preferably within the proposed Department of Community Development, funded by a small percentage assessment on funds appropriated for relevant federal programs.

Federal Government Population Research

The Commission recommends that the federal government foster the "in-house" research capabilities of its own agencies to provide a coherent institutional structure for improving population research.

Support for Professional Training

The Commission recommends that support for training in the social and behavioral aspects of population be exempted from the general freeze on training funds, permitting government agencies to support programs to train scientists specializing in this field.

Organizational Changes

The Commission recommends that organizational changes be undertaken to improve the federal government's capacity to develop and implement population-related programs; and to evaluate the interaction between public policies, programs, and population trends.

Office of Population Affairs, Department of Health, Education and Welfare

The Commission recommends that the capacity of the Department of Health, Education and Welfare in the population field be substantially increased by strengthening the Office of Population Affairs and expanding its staff in order to augment its role of leadership within the Department.

National Institute of Population Sciences

The Commission recommends the establishment, within the National Institutes of Health, of a National Institute of Population Sciences to provide an adequate institutional framework for implementing a greatly expanded program of population research.

Department of Community Development

The Commission recommends that Congress adopt legislation to establish a Department of Community Development and that this Department undertake a program of research on the interactions of population growth and distribution and the programs it administers.

Office of Population Growth and Distribution

The Commission recommends the creation of an Office of Population Growth and Distribution within the Executive Office of the President.

The Commission recommends the immediate addition of personnel with demographic expertise to the staffs of the Council of Economic Advisers, the Domestic Council, the Council on Environmental Quality, and the Office of Science and Technology.

Council of Social Advisers

The Commission recommends that Congress approve pending legislation establishing a Council of Social Advisers and that this Council have as one of its main functions the monitoring of demographic variables.

Joint Committee on Population

In order to provide improved legislative oversight of population issues, the Commission recommends that Congress assign to a joint committee responsibility for specific review of this area.

State Population Agencies and Commissions

The Commission recommends that state governments, either through existing planning agencies or through new agencies devoted to this purpose, give greater attention to the problems of population growth and distribution.

Private Efforts and Population Policy

The Commission recommends that a substantially greater effort focusing on policy-oriented research and analysis of population in the United States be carried forward through appropriate private resources and agencies.

Separate Statements

Separate Statement of Marilyn Brant Chandler

Beyond my own personal feelings, I oppose open abortion on demand and support limited therapeutic abortion laws for the following reasons:

1. The Commission report does stress that abortion should not be a substitute for birth control, but has not intimated that liberal abortion takes the responsibility away from sexual activity. Impulsive, irresponsible sexual involvement can be rationalized without fear of pregnancy if abortion is open, legal, and free.

2. My pragmatic feeling is that the United States is not ready for abortion on demand because:

> Government agencies and politicians shy away from the issue.
>
> Fifty states have 50 differing laws, though this is wrong, for laws should be uniform across the nation. These differing laws will take a long time to change. States will adopt a therapeutic law before adopting an open law.
>
> Abortion is still a major moral issue.
>
> Our Commission's public opinion poll indicates that, though 50 percent were pro-abortion on a patient-to-doctor relationship, the other half approves it not at all or half-heartedly.
>
> Title X of the Public Health Service Act and the Economic Opportunity Family Planning Act will not fund or support abortion.
>
> Conflicting state and federal court interpretations on the legal right of a fetus will not be resolved until a nationwide law or court decision is passed.

Until public opinion conclusively fights the strong groups opposing open abortion, the American Law Institute model presents a more acceptable alternative than open abortion. This model, admittedly, has deficiencies in defining the mental health of a woman or in its egalitarian selection. However, I advocate therapeutic abortion on the basis that: (1) abortion is a decision between woman and physician; (2) it is approved by a hospital committee; (3) it is performed in a hospital or accredited clinic; and (4) the limit for the gestation period does not exceed 18 weeks.

Separate Statements of Paul B. Cornely, M.D.*

Legal Impediments for Minors

The recommendation that contraceptive information and services be made available to minors is indeed objectionable when it is applied to all minors. There is no question that this should be so in reference to those who are acknowledged to be emancipated minors, such as married teenagers or self-supported ones who may be living within or outside their parents' home. In this instance, the same guidelines and safeguards which have been noted for family planning services should apply. It should be voluntary, with due consideration given to the religious beliefs and culture of the individual; supporting services such as counseling and social service should be available; emphasis on privacy, consideration and the dignity of the individual should be always present; and there should be ease of accessibility for everyone.

On the other hand, when we as a society accept the responsibility of giving contraceptive advice and services to those who are minors living in a family unit, then we are striking at the foundation and roots of family life, which are already weakened by our misuse of affluence and technology. First of all, it should be stated that the age of menarche or beginning of menstruation is continually going downwards, so that today it is about 12.5 years. The implications of this are indeed obvious and need not be belabored. What is of greater importance is that our society has the responsibility to provide the kind of family life, education, neighborhood, recreational facilities, and creative outlets which would make it possible for all minors to live in an environment which would be conducive to the growth and development of the child which is due him. If this affluent society cannot do this, then it has failed miserably and does not deserve to continue to exist. Contraceptive approach to minors is the cheapest and most irresponsible way for our society to solve this problem.

Abortion

The majority's recommendation that a nationwide abortion-on-demand law modeled after the New York State statute be adopted cannot be supported. Abortion in the opinion of this Commissioner is destruction of human life since it kills the fetus; and society through

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**See also concurrence with statement of Commissioner Otis Dudley Duncan on page 153*

its laws has a responsibility to protect all human life. Support for this concern can best be expressed by discussing some of the issues raised in this section.

The Law: The argumentative posture of these paragraphs is exclusively that of the pro-abortionists, namely, that abortion legislation has been no more than a health measure postulated on the welfare of the *mother* only. This section of the report does not even make an attempt to provide a legal accounting for the unborn developing child.

The Moral Question: This section of the report proposes that only *one* moral principle be the controlling factor in the abortion situation: the woman's freedom to reproduce. Such moralistic monism, simplistic as it is, at bottom fails to consider the freedom of the unborn child to live. Overall, the arguments of this section would make some sense if the topic was a woman's right to use preventive contraceptive methods.

For all its language about moral sensitivities, the text seems completely oblivious of the fact, much less the implications, of defining a segment of humanity as "unwanted." The Commission does not face the question: What does it mean as public policy to legitimate the destruction of "unwanted children"?

Public Health: The report overrates the problems of illegal abortions as much as it overrates the feasibility of unrestricted abortion laws to solve what problems there really are. Most of the data cited in this section of the report come from New York City, and are based on a limited experience. This is concerned almost exclusively with the *short-range* effects of abortion on the mother's health (at that, there is no way of following up on the out-of-staters). The data from Russia, Eastern Europe, and Japan on the negative *long-range* effects of abortion on a woman's reproductive system are ignored.

It also should be noted that the overall maternal death rate, even with the presence of restrictive abortion laws, has been steadily declining for years. The role of positive maternal health care has been overlooked.

The *complete failure* to consider even the massive destruction of developing fetal life as some kind of balancing factor in public health is but an indictment of the myopic point of view of this section.

Family Planning: The report ignores the evidence in England, Japan, and the Eastern European countries that the easy availability of abortion destroys motivation to have consistent recourse to preventive contraception methods. As the text reads, the Commission would be saying that it believes that the transition from the abortion mentality to the preventive contraceptive mentality could be achieved by the simple presence of adequate contraceptive technology. If such would be the case, this would be the first time in human history that technology has ever solved a specifically human problem. This faith in technology is hardly justified, either historically as regards technology or specifically as regards family planning.

Demographic Context: It is highly ironic that a Commission concerned with population policy should settle for the kind of scattered information that is available regarding the demographic impact of abortion, yet would recommend unrestricted abortion as public policy. In this section, the Commission practically writes off the demographic impact of abortion as a significant issue for the United States.

Population Stabilization

This Commissioner is one who identifies with the third position in Chapter 1 and firmly believes that population growth is indeed not the major problem in our society and that, of more import, is the need for a radical rearrangement of our values and priorities as well as the relationship of man to himself, of men to each other, and to the earth from which we sprang. As René Dubos stated in a speech which he made before the Smithsonian Institution on October 2, 1969, entitled "Theology of the Earth," the first chapter of Genesis tells man and woman to replenish the earth and subdue it; but of more importance is the second chapter wherein man is instructed to dress and keep the land. This means that man must be concerned with what happens to the land and its resources.

It is of particular importance to keep this in mind because, many times throughout the Report of the Commission, the need to speak in terms of statistics about people, rather than about people themselves, may leave the impression that human beings are looked upon as things or chattel which can be equated in terms of numbers or quantities; what it costs to produce them; what is the supply and demand; and how they can be moved or rearranged.

This then brings me to the recommendation of this chapter on population stabilization. I voted for it, but I would not want anyone to believe that the phrase, "the Commission recommends that the nation welcome and plan for a stabilized population," is intended to mean that I would support any national or state governmental policy or regulation which would in any way interfere with the desires, aspirations, and needs of any family concerning its size or number. For our government to interfere with this sacred trust given to each family

would be to bring Orwell's 1984 prediction closer to reality. My intent is expressed by the following statement of goals by the Commission: . . . creating social conditions wherein the desired values of individuals, families, and communities can be realized; equalizing social and economic opportunities for women and members of disadvantaged minorities; and enhancing the potential for improving the quality of life.

Separate Statements of Alan Cranston

I agree with most of the views expressed in the final version of the Commission Report. Many of my early concerns over specific portions of prior drafts were eliminated in later revisions. But, as with the other Commissioners, my concurrence in this Report should not be interpreted as meaning that I necessarily agree with every statement or always with the wording chosen. I do want to make the following comments on the views expressed by the Commission on a few specific substantive points.

Resources and the Environment

I agree with the conclusion reached in this chapter that a lessening of population growth will buy us some time in the struggle to maintain a livable biosphere. The Commission's mandate was to study the effect of population growth on our environment and natural resources, and the models on which its studies were based emphasize the population factor. Those reading the Report should keep this in mind.

The Report argues that continued population growth inevitably speeds up the depletion of natural resources and requires rapid technological development—to meet the ever-increasing demand for goods and services—all of which increase environmental pollution.

Proceeding from this assumption, the Report attempts to show the impact of population on the environment by "using a quantitative model which shows the demand for resources and the pollution levels associated with different rates of economic and population growth." If the Commission's use of this quantitative model—appropriate for the Commission's function—were to be misunderstood, unintended and unjustified conclusions could be drawn from it about the Commission's view of the relationship between population growth and environmental degradation.

This bears clarification, for, in *The Closing Circle*, Barry Commoner comments on the danger of this kind of approach to the environmental problem:

> This approach, it seems to me, is equivalent to attempting to save a leaking ship by lightening the load and forcing passengers overboard. One is constrained to ask if there isn't something radically wrong with the ship.

His point is well taken.

Population pressures did not lead soap manufacturers to switch to detergents.

Population pressures did not lead farmers to the use of pesticides and chemical fertilizers.

Population pressures did not lead our cities to the abandonment of public transit systems nor to our public's dependence on the private automobile.

Population pressures did not develop the too-big and too-powerful American automobile.

Population pressures did not bring about the switch to flip-top beer cans and nonreturnable bottles.

Population pressures did not fill our homes with myriad electrical gadgets.

Most of our environmental disasters have been the technological successes of an economic system where the goal is to use technology to maximize profit.

The ecologically unsound technological developments of the past two decades would have created the environmental crisis even if the population had been stable during that period.

The final few pages of Chapter 5 tend to balance out the preceding emphasis on population as the cause of environmental deterioration. However, the Report states that: "Population growth is clearly not the sole culprit in ecological damage." I would like to point out that population growth is not the major culprit, either. The major culprit is the manner in which we use, control, and evaluate our technology.

Slowing population growth will give us time to reevaluate and change our technology, but it cannot substitute for the changes which must be made if we are to survive.

Population Education

The Commission recommends enactment of a Population Education Act and presents a persuasive case for a greatly enlarged federal effort. I was the Senate author of both provisions in the present law cited by the Commission dealing with federal assistance in the development and implementation of population educa-

tion programs, materials, and curricula—in the Family Planning Services and Population Research Act (P.L. 91-572) and in the Environmental Education Act of 1970 (P.L. 91-516). As Chairman of the Special Subcommittee on Human Resources of the Senate Labor and Public Welfare Committee, I also conducted oversight hearings on the Administration's failure to implement these programs.

But I am not at present certain in my own mind whether it would be more appropriate to achieve our ends legislatively by amending existing laws or by enacting an entirely new statute.

Legal Impediments for Minors

The Commission recommends the elimination of legal barriers to, and the establishment of, programs for the distribution of contraceptive information and services to all, including unmarried teenagers. I support fully the Commission's purpose: to eliminate the suffering which an unwanted birth often produces both for mother and child. The means of implementing the Commission's recommendation that such information and services should be provided without parental consent to unmarried teenagers living in the home concern me, however.

I do not believe the Commission has placed sufficient stress on the role and responsibilities of parents regarding the provision of birth control information and services. Although I believe appropriate discussion of reproduction, birth control, and venereal disease should be included in the basic school curriculum for adolescents, I also believe it would be a mistake to place our principal emphasis on that method of education. Society and schools should make every effort to encourage child and parent to discuss these matters honestly and openly. Our educational programs should stress this.

I have similar concerns about medical authorities providing contraceptive services to unemancipated teenagers without parental consent or knowledge. I strongly believe that it should be the obligation of the health professional to counsel the unemancipated teenage patient to raise this issue with his or her parents. Nonetheless, despite my serious concerns on this question, I concur that it is poor public policy for pregnancy to be treated as a kind of moralistic punishment for what some may consider promiscuous sexual behavior.

Abortion

Although the Commission expresses strong concern—which I share fully—over the danger that abortion may be used as a means of birth control, the Commission also recommends the adoption of state laws permitting abortion upon a pregnant woman's request, provided it is performed by licensed physicians under conditions of medical safety.

I am unable to join in this recommendation because I hesitate to endorse governmental sanction of the destruction of what many people consider to be human life. I am particularly concerned by the social and ethical implications of such action now, given the general atmosphere of violence and callousness toward life in our society and in our world. Ours has become an incredibly violent time. Our people are involved in acts of violence both in our streets and in Southeast Asia. Meanwhile all mankind exists under the dark shadow of the strategy of nuclear terror with its threat of sudden death for all of us.

Has life ever been held more cheaply? Has there ever been greater indifference to the taking of life? Are we really aware of just how hardened we have become?

I wonder if, in this atmosphere, we are capable of making a wise decision on this issue involving our very attitude toward human life. Perhaps we should wait for a more compassionate and less callous time.

I want to make it plain that I recognize the inconsistencies and inequities involved in many existing state laws permitting abortions for "therapeutic" reasons. They have the effect of depriving low-income persons of equal access to medical procedures readily available to the more affluent. Such laws, along with the even more restrictive or prohibitive laws in some states, result in utter tragedy for women who, unable to afford travel to another state or abroad to obtain an abortion, turn in desperation to illegal abortions and suffer butchery that often destroys both the fetus and the mother.

I understand and respect the view that many people hold that abortion is fundamentally a question of a woman's inherent right to control her own body. But I also understand and respect the view of many others that a second body also is involved—a human fetus. And, as I have indicated, I am concerned about the effect of all this on still a third body—our society itself.

Illegal Aliens

• The Commission recommends that Congress enact legislation to impose civil and criminal sanctions on employers of illegal border-crossers or aliens who are in an immigration status which does not authorize employment. Such a statute would, in my judgment, impose on employers an onerous burden of having to ascertain in fact whether each individual is in a proscribed category. This could very well have a chilling effect on hiring in international border areas, thereby seriously jeopardizing employment opportunities for Mexican-Americans.

Only in the case of an employer who knows or has clear reason to know that an employee is within a proscribed category would I favor imposition of any criminal or civil penalty.

One burden I would place on the employer is that he inquire about the citizenship of each prospective employee. If the applicant states he is an alien, the employer should require submission of evidence of lawful admission for permanent residence or of authorized employment status. (I note that section 14 of S. 1373, currently pending before the Senate Committee on the Judiciary, contains such a provision. Also, a law recently enacted in California as section 2805 of the Labor Code penalizes employers who deprive lawful residents of jobs by knowingly hiring illegal aliens.)

I think we need to find better ways of halting the employment of illegal aliens, while at the same time not imposing onerous or counterproductive burdens or restraints on employers. Two that I am considering are:

1. Requiring that Social Security cards issued to aliens be of a different color, or in some way clearly distinguishable, from those issued to citizens. (We would need to make sure, however, that citizens are not unreasonably put to great trouble in producing evidence of citizenship in order to secure a Social Security card.)

2. Requiring each prospective employee to complete a non-notarized affidavit form regarding his or her United States citizenship. Material false statements would be punishable under the Federal False Statements Act.

It is important that in coping with the employment of illegal aliens, we consult with those population groups most directly affected. It is equally important that we do not choose a remedy that imposes special burdens on any geographical, ethnic, or racial group.

Depressed Rural Areas

In discussing the goals of our population policy as it relates to migration and economically depressed rural areas, concepts such as population maldistribution and the need for population dispersion take on real meaning only after careful analysis of the economic and social consequences of the changing structure of the agricultural industry. However, I wish to make certain observations about what *causes* people to leave rural America.

Of the 5.5 million individual farms that existed in 1950, only 2.9 million remain today. If present trends continue, there will be fewer than two million farms in 1980. In other words, 900,000 farms will disappear in the span of just eight years. Some 900,000 farm families will be forced to seek their livings outside of farming—often in already overcrowded urban centers where they are ill-equipped to compete in a job market that requires skills and training unacquired in rural life.

The structure of modern agriculture is changing dramatically. Twenty to 30 years ago, the rural landscape was dotted with family farms and small, thriving communities. Today, small farmers are being blown off their land by the winds of economic and technological change. Farms are increasingly large scale and mechanized; the farming industry is increasingly dominated by giant corporations and conglomerates that buy up prime farmland and seek the total vertical integration of the industry from "seedling to supermarket." The production, processing, marketing, and distribution of agricultural commodities are increasingly controlled by huge corporate entities that have little, if any, stake in the rural community. With an economic base that is primarily urban, these agri-industries siphon off what few economic resources are left in rural America.

The Commission's statement that "many places have simply outlived their economic function" could be interpreted as an acceptance of the myth of the inevitability of bigness of agriculture. The unfortunate reality is that corporations and conglomerates are moving into farming not because smaller units are inefficient, but because present federal policies are encouraging these entities to diversify into agriculture by providing them with tax benefits and other economic incentives. Their presence in agriculture—and the nonfarm resources they control—make it virtually impossible for the independent farmer to compete successfully, even though he is likely to be the more efficient farmer.

If we are to discuss maximizing freedom of choice

about where an individual wants to live and work—and I believe such freedom is essential—we must make it possible for the independent farmers and businessmen of rural America to survive economically. As the Commission notes, we must build up the economic and social base for the maintenance of rural communities so that people have a real choice about where to live and to work. We must also resist the temptation to assume that we can revitalize rural America only by bringing in new industry. Although rural communities desperately need infusion of new capital, industrialization alone will not provide jobs and economic stability there in a manner consistent with environmental and social quality.

It is vital that we examine these issues in more detail if we are to develop and implement viable national policies and priorities that can achieve a better rural/urban population balance.

Department of Community Development

The Commission recommends that Congress enact legislation to establish a Department of Community Development to undertake, among other things, research on the interactions between population growth and distribution, and the programs such a Department would administer. I agree that this research is necessary. An administration bill, S. 1618, to establish such a Department, is pending before the Senate Committee on Banking, Housing and Urban Affairs, of which I am a member. But until I am able to resolve all the difficult issues involved in creating this super-Department—including the implications of removing the community action program from the Office of Economic Opportunity—I believe it would be premature for me, as a member of the authorizing committee, to join in this Commission recommendation.

Separate Statement of Otis Dudley Duncan, concurred in by Paul B. Cornely, M.D.

We inquire what is the effect of a growing population on a "healthy economy." But the majority of the Commission, no doubt wisely, did not care to inquire into what may constitute "health" in regard to an economy. We accept projections to the effect that, three decades hence, "the average individual's consumption is expected to be more than twice what it is today" without inquiring whether a doubling of consumption every 30 years be a sign of "health," or, perchance, of some disease whose horrors will only be disclosed to us by degrees. The Commission cannot plead that the proper questions were not raised before it, for they are trenchantly stated in the paper, "Declining Population Growth: Economic Effects," prepared for the Commission by J. J. Spengler. I wish to conclude this statement with a quotation from Spengler's paper:

> Today it is assumed that the economic circle can be squared; for . . . it is supposed that a society may have guaranteed full employment, price-level stability, strong producer pressure groups (trade unions, business and agricultural groups, government employees), and freedom from direct economic controls. In reality, of course, it is impossible for these four objectives to be realized simultaneously; only two, possibly three, are compatible. The policies driving the American economy are much more directionless than those which animate the Strassburg goose and the Sumo wrestler to eat continuously, the one to become liver pâté and the other to "belly" one of his kind from the ring; for this economy, with its momentum based upon destruction of a finite earth's depleting resources, neglects the fundamental requirement for survival, namely, conducting its affairs in keeping with an infinite time or planning horizon.
>
> Ultimately, attainability of a population goal compatible with the finiteness of that part of the biosphere accessible to the American people turns on what happens in the moral realm—on determination of the content of this goal and construction of a penalty-reward system calculated to make the goal realizable. Market forces alone cannot assure its realization, for the reasons that make exchange, though the main organizing principle, inadequate without appropriate institutional and legal underpinnings. A population goal cannot be settled upon in isolation, but must be viewed as one of a set of interrelated goals, the attainability of any one of which turns on the weight attached to other goals within the framework of a finite physical as well as social environment.

Separate Statements of John N. Erlenborn

Child Care

In this section, the Report recommends a universally available child-care system. In the sense that the Commission holds voluntary participation to be essential, the Commission's position that participation in a child-care program not be a condition for other governmental assistance is not inconsistent. What is difficult to reconcile is the contention that a child-care system affords opportunities for learning, development, and companionship; but government should not require the people it supports to utilize these opportunities. These are the very people who, through little fault of their own, are otherwise isolated from these advantages and, as a consequence, from the mainstream of society. Thus, they are the very people who have the most to gain from exposure to child-care programs, but who may, understandably, be the most hesitant and apprehensive about volunteering.

In fairness to them, I believe they deserve priority in any child-care system financed by the federal government. In fairness to those who pay the bill for any government-sponsored program, I believe the government has the responsibility to set conditions which attempt to assure fulfillment of the program's goal. This should be no less true in the case of the welfare program, where one of the goals is to assist people in finding a meaningful and contributory niche in society, than it is in any other program.

All this is not to say I am prepared to support the Commission's recommendation for government to subsidize—beyond the tax relief recently enacted—a comprehensive child-care program of sufficient proportions to accommodate all those who want to participate. If the demand for child-care service continues to grow—and that seems to be the sign of the times—I believe those who want it should be willing to pay for it, if they can.

I am also convinced that pre-kindergarten education should not be established as a separate federal school system, but should be integrated with other private and public education.

Children Born Out of Wedlock

I agree with much of the analysis presented in this section on the need to reduce the social and moral stigma attached to children born out of wedlock. It is no fault of the child that the circumstances of his birth may have been deemed irregular by society. Thus, anything that this Commission's recommendations can do to reduce or eliminate the social and moral stigma is appropriate.

I am not, however, similarly convinced that the legal ramifications of the distinction between legitimacy and illegitimacy have been fully analyzed by the Commission in sufficient depth to enable it to recommend that the legal status of a child born out of wedlock be the same as a legitimate child. The purpose of the legal discrimination was not, as the Commission states, to protect the sanctity of family and discourage extramarital sex, so much as it was to clarify and make more certain the inheritance of property and the rights of individuals to legally obligate others. Even if the purpose had been to protect the family and discourage extramarital sex, the fact that the goal has not been realized causes me to argue against the relaxation of restrictions; it could easily be argued that the restrictions should be tightened, not weakened. By analogy, one could also argue that since laws against murder have not eliminated murder, they should be abolished.

The examples cited in the Report of reductions of discrimination only point out the complexities of the matter. For example, the amendments to the Social Security Act recognize, appropriately, certain conditions such as contributions to the support of the child by the father or a court decree identifying the father as a necessary precondition, a substitute, if you will, for marriage, "legitimizing" the status of the child. Unless there is some overt act of assumption of responsibility, the distinction is not removed.

Because of the complexities of the matter, I can agree that research and study by the American Bar Association, the American Law Institute, and other groups concerned with state laws are appropriate. I cannot, however, join in the Commission's recommendation that all legal distinctions between legitimate and illegitimate children be eliminated.

Women: Alternatives to Childbearing

Throughout this section, there runs the refrain that our primary object and goal is to provide greater freedom to the individual in society. In urging the adoption of the Equal Rights Amendment, the Commission may be inciting the substitution of greater regimentation and control rather than encouraging the expansion of individual freedom.

We are a pluralistic society. The vitality, the experimentation, the openness of our society is directly attributable, I believe, to the fact that we are free to

march to the tune of different drummers. To force our citizens into a straitjacket of conformity and sameness would stultify individuality and undermine freedom. Yet I believe that in the name of equality such a course of action is being proposed here.

Women have been discriminated against in employment, in education, in legal arrangements, and in family relationships. I do not question this. To employ a blunderbuss, through enactment of the Equal Rights Amendment or the anti-sex-discrimination amendment to the education laws, however, can harm as many or more than it can help; and there is a better way to put an end to discrimination against women.

Wherever discrimination exists which deserves government action to overcome it, efforts should be made—and are being made—to provide remedies through measured steps, where facts are gathered, causal relationships established, and the margin for serious error reduced. In the enactment and now the strengthening of the Equal Employment Opportunity Act, this has been done. Similarly, it appears that both Houses of Congress have agreed upon the need to eliminate clearly illogical and harmful sex discrimination in the areas of vocational education and graduate higher education. Correctional action is also being taken to equalize the property rights of women and their status as heads of households.

The goal of the Equal Rights Amendment is to eliminate distinctions between men and women in the law, but there can be distinction without discrimination. Treating people differently, respecting their individual needs and desires, looking upon them as unique human beings—not as a part of a statistical herd—is not discrimination. Treating everyone alike, regardless of their preferences, however, is all too often discriminatory.

Many women find enjoyment and gratification in remaining home, being mothers, and rearing children. Eliminating laws which protect that status is every bit as discriminatory as any efforts to impose such a status or role. Adoption of the Equal Rights Amendment, in particular, would not only have this effect, but would tie the hands of Congress and the people in efforts to recognize the uniqueness of individuals and their right to pursue their own objectives.

For over a century, organized labor has struggled to obtain protections for women who must or who choose to work. I would assume that, if polled, most women would elect to preserve these safeguards. Yet that which took many years to obtain would be undone overnight if the Equal Rights Amendment were adopted.

Serious erosion to individual freedom is also threatened in the area of education through either the enactment of the Equal Rights Amendment or legislation that permits the federal government to write admission policies where discrimination based upon sex has not been proven to exist. While no one can tolerate the denial of the opportunity for an education or fair consideration for employment in the field of education, the fact is that the great strength of America's educational system since the founding of the nation has been its freedom from government dictation and control. Diversity and autonomy have been its hallmarks. This has included the establishment of a variety of options which have been made available to students, ranging all the way from totally one-sex schools to equally balanced coeducation.

The organization of education has been based on that which is best educationally for the individual, not on what mathematical ratios dictate. To prohibit such diversity and autonomy through the imposition of uniform requirements would constitute a clear and present threat to our educational institutions.

In graduate, professional, and vocational education, and even in some of our public undergraduate schools, the evidence is clear that discrimination—not diversity—exists. This should be corrected, and corrective legislation is in the offing. However, we have seen no indication that those who seek an education at other levels and in other areas are prevented by reason of sex from attaining their goal.

While figures on elementary and secondary education are unavailable, the record discloses that, in undergraduate education, females continue to represent a larger percentage of total enrollment, increasing from 31.7 percent in 1946 to 41.1 percent in 1970. For first-time undergraduate enrollment, the percentage increased from 28.3 percent in 1945 to 44.7 percent in 1970. In these same years, females represented 56.8 percent and 50.5 percent of the number graduating from high school.

In sum, the fault I find with any remedy that attempts to cure a variety of ills with a single stroke of the pen is that it ignores the individual, removes the good with the bad, and erodes principles which only peripherally touch upon the ills at which the remedy is directed. Overall, the effect is to discriminate where discrimination does not exist, and to restrict rather than to free. I believe these pitfalls are inherent in the Equal Rights Amendment and the recommendation that the

federal government direct the admissions of our elementary and secondary schools as they relate to sex. Specific legislation to correct proven problems will permit us to avoid these pitfalls.

Legal Impediments for Minors

I am compelled at the outset in commenting on this section to offer an observation: I do not believe the Report is proposing that contraceptive devices be sold through vending machines in school corridors, and I hope it will not be so construed.

As to contraception, the law, and minors, I wish the Commission had applied an age qualification to the term minor. Even so, I cannot join in the Commission's recommendation that all legal restrictions on access to contraceptive information and services should be eliminated to permit minors, youngsters under the age at which they are legally responsible for themselves, unlimited access to contraceptives and abortions.

As I have stated elsewhere, the goal of increasing the quality of life should not be paramount to the sanctity of life. The exercise of any right in excess can lead to license.

Throughout this Report, the emphasis on the rights of the individual is used to justify increased individual freedom and responsibility. Yet, the facts cited in the Report, particularly when dealing with questions of minors, show that minors are often inexperienced and ill-equipped to deal with the questions that the new freedom gives them.

I would have preferred that the Commission qualify its recommendation to give greater weight to circumstances and the need for parental guidance. I can fully support the recommendations that the consequences of illegitimacy and teenage pregnancy be reduced so that the mother will have a chance of enjoying a satisfying life. The tensions associated with what is, perhaps, an unwanted pregnancy should be reduced. At the same time, however, we should not detach ourselves, as the Commission does, from the related moral and social questions.

By eliminating any need or concern for parental guidance, the Commission essentially takes the view that the child knows better than the parent what his rights and responsibilities are. This, in my view, goes too far in placing emphasis on individual right, and tends to ignore responsibility for one's own actions.

A particular fear haunts me with regard to the lack of a recommendation that teenagers be exempted from laws permitting voluntary sterilization beyond the assumption that usual and accepted medical judgment will be exercised.

I do not know of any age a human being passes through that is more impressionable, more susceptible to suggestion, than the teen years. To couple this impressionability with access to sterilization without parental guidance can mean that many youngsters, in their zeal to be patriotic, to do something for mankind, will know more than a few moments of torment and regret.

It is no answer, to my mind, to these young people and others merely to suggest that sperm banks can alleviate concern about a change of mind. Technology in this area has not advanced to the stage that permits this guarantee. And, finally, the moral questions posed by artificial insemination remain unresolved.

Abortion

I cannot accept the recommendation that present state abortion laws be liberalized to allow abortions to be performed on request.

My basic premise is that we must include within our concern for the quality and enhancement of life a respect for life itself—indeed, it should be paramount. Otherwise, the concern for the enhancement or enrichment of life is entirely materialistic. Thus, I believe the Report should have resolved the moral and ethical issues it raised. The Report could have served a useful purpose at this point by a more wide-ranging discussion of these issues. Instead, it does nothing to clarify the fundamental bases on which people now quite rightly object to liberalized abortion.

A discussion of the moral and ethical issues, I realize, is not an easy task. How, for instance, do we distinguish between abortion and infanticide? The goal of relieving the mother of the burdens of child-rearing is the same; thus, some distinction between the means must lead to a recommendation of the one and not the other.

At what point in the development of the fetus do we consider it to be human life worthy of the protection of society? And what event signals the change of the fetus from the state of nonhuman to human? My own view is that the fetus is a new, separate human being from the moment of conception.

It would be helpful for those reading this Report to be able to review the reasoning leading to the judgment that liberal abortion is morally defensible. In my own view, it is difficult, if not impossible, to reach that moral judgment, and yet stop short of justifying

infanticide, euthanasia, or the killing of the severely mentally or physically handicapped.

I believe that the failure of the text to resolve these questions of moral judgment places the recommendation outside a moral context.

Viewed within a moral or ethical context, I do not believe that this society can accept the destruction of human life for the comfort or convenience of individuals within the society.

Furthermore, the recommendations do not reflect the complexity of potential situations in which abortion may be called for. It does not distinguish, for example, between the rights of married and unmarried women to request abortion. What may be appropriate for an unmarried woman to decide between herself and her doctor may be completely inappropriate for a married woman, who thus ignores the rights of her husband. Moreover, there are numerous distinctions of a medical nature which could be made to limit the scope of the recommendation.

In this section, the Commission notes the difficulty of assessing the demographic impact of liberalized abortion. Its impact would be small, no doubt less than that of immigration. And yet, abortion on request takes precedence as a recommendation over one concerning the limiting of immigration. Since this is a "Population" Commission and not a "Birth Control" Commission, what compelling consideration leads the Commission to make this very controversial recommendation when it has little or no population or demographic consequence?

In summary, for all of the reasons noted, I find it impossible to join with the Commission in these recommendations.

Methods of Fertility Control

A trait common to groups and organizations concerned about a particular problem is citing their issue as one of highest priority, but failing to view it in the context of other problems that confront us as a nation. Obviously, not all of the myriad dilemmas we are trying to solve can be classified as being of highest priority.

Specifically, the Commission recommends that this nation give *highest priority* to fertility control research and that the full $93 million authorized for this purpose for fiscal year 1973 be appropriated and allocated. Next, it recommends that federal expenditures for such research rise to a minimum of $150 million by 1975.

To put the full funding recommendation in perspective, it is necessary to examine the definition of the word "authorization" as it pertains to legislation. In simplest terms, it sets a limit on the amount that may be appropriated for a given purpose. It is a figure that, more often than not, is merely taken from thin air. Rarely does an authorization reflect a diligent inquiry into actual needs or a search for an amount that can be efficiently and effectively expended during a defined period.

If Congress were to heed the cry for full funding of each of the authorizations it makes, the federal budget would be more than three times the $246.3 billion requested for fiscal year 1973. The amount of the federal debt would be imponderable.

Viewed in this light, the necessity to evaluate each request for funds alongside all of the other requests in the budget as a whole is clearly evident. The Report notes that amount expended thus far by the federal government for fertility control research is modest in terms of total research expenditures, but no attempt is made to assess this demand for funds as they relate to the thousands of other funding demands.

In like manner, the Report makes specific recommendations for funding levels of family planning projects. We are not suggesting that the amounts recommended are either too high or too low, but rather that they are merely judgments; and we do not want to judge funding levels for these purposes in isolation from funding requests for all other programs.

Equally important, the discussions on funds do not take into account the fact that federal support for family planning services and fertility control research in fiscal year 1973 will rise to $240 million, a threefold increase since fiscal 1969.

Fertility-Related Services

The Commission recommends that both ". . . public and private health financing mechanisms should begin paying the full cost of all health services related to fertility, including prenatal, delivery, and postpartum services; pediatric care for the first year of life; voluntary sterilization; safe termination of unwanted pregnancy; and medical treatment of infertility." Moreover, the Commission suggests: "The same type of coverage could be built into existing private insurance programs."

Either way, it seems to me, the public pays. Indeed, perhaps the public is willing. I suggest, however, that in making that decision several considerations warrant examination.

First, of course, it is important to ascertain the present direction of private insurance. Those of us who do not earn our livelihood through the private insurance system know that health insurance (and my reference to health insurance includes the whole gamut—medical, surgical, hospital, major, and comprehensive) is costly. What is more, we know it does not provide all the benefits we seek and premiums go up when new benefits are added. We can probably all agree as well that the only way medical expenses are going to go is up. And we rightfully ask whether private insurance can provide a remedy.

In its 1971-72 report, the Health Insurance Institute tells us that some 170 million Americans under age 65 were protected by one or more forms of private health insurance in 1970. Despite Medicare, which serves those over age 65, over 11 million more persons, or 59 percent of the total population age 65 and over, carried private health insurance policies to supplement Medicare in 1970.

From its birth in 1950 until 1970, major medical expense insurance—wherein each individual pays the first $100 or so each year for health expenses and 10 to 15 percent of expenses over the deductible amount—had expanded to cover 78 million people.

Without a doubt, the system is responsive, flexible, and expandable, but nonetheless in need of improvement. The question is, what form marks improvement?

It is my conviction that additional expenditures, be they public or private, for health-related costs should be devoted to answering our needs for more medical personnel (a program already under way, I should point out), to allaying the burden to individuals of prolonged or unusually heavy medical expenses, and to preventive medicine.

It seems to me we must recognize that this nation has basic needs that government can and must meet, but our nation's capital is not a bottomless well from which we can pump endlessly without fear of the well running dry. There is a limit, and genuine priorities must be set. Surely public subsidy of sterilization and abortion should not come at the head of the list of priorities.

Separate Statement of D. Gale Johnson

After the Commission had approved the section on "Racial and Ethnic Minorities," a study by Finis Welch of the Graduate Center, City University of New York and the National Bureau of Economic Research, came to my attention; this study throws new and important light on the returns to education for blacks and whites. The comparisons in the text on income by education are for males 25 years of age and older and seem to indicate that income gains from increased education, especially college education, are very small for blacks. Mr. Welch undertook a new analysis of the 1960 Census of Population data in which the data for both whites and blacks were analyzed by estimated years of work experience. In effect, the years of work experience was the number of years since each individual left school.

His conclusion with respect to the analysis of income and education data for 1959 was:

> In the 1959 data, the evidence is that for persons with 1-4 years of experience, black earnings rise relative to white earnings as school completion levels increase. This point has not been previously noted. For persons with 5-12 years of experience, the black/white earning ratio is insensitive to schooling and for persons with 13-25 years of experience the relative earnings of blacks falls as schooling increases.

A similar analysis of data for 1966 reveals two results of great significance. First, for blacks who entered the labor force in 1959 or later, the percentage increase in income for each additional year was substantially greater than for whites. Second, blacks who entered the labor force between 1947 and 1958 retained the same percentage income gains from an additional year of schooling relative to the income gains for whites in 1966 as had been found for 1959.

These conclusions are consistent with the behavior of black young men and women. In the last two decades, there has been a substantial narrowing of the gap between the number of years of schooling completed by blacks and whites. In 1969, blacks who were 25 to 29 years old had a median years of school completed of 12.1 years compared to 12.6 years for whites. For persons who were 45 to 54 years old in 1969, the median years of schooling completed was 9.1 for blacks and 10.9 for whites.

Mr. Welch's study and, more importantly, the decisions made by young black men and women cast considerable doubt upon the quite strongly held view that the returns to education for recent entrants to the labor force is now substantially lower for blacks than for whites. That the returns to education for blacks who entered the labor force before the late 1940's is below

the return realized by whites is not in doubt.

It is good that the data from the 1970 Census of Population will soon be available to permit further analysis of the returns to education.

Separate Statement of John R. Meyer

Forecasting economic events even for a few months into the future is a hazardous exercise. Making extrapolations for three decades or so, as one is required to do if one is to forecast the impact of demographic developments, is an even more uncertain undertaking. The Commission was therefore commendably cautious in asserting what it could identify as the probable economic impacts of slower population growth.

Nevertheless, there exists a growing body of highly interesting, though speculative, literature on what the many different economic facets or aspects might be of slower population growth. Some of these contributions were done at the request of the Commission and will be issued as supplemental research reports. These comments, in fact, are largely drawn from those reports.

Perhaps the most important of these speculations concerns the possible impact of slower population growth on the extent and incidence of poverty in the United States. It seems highly probable that per capita incomes overall will be almost 100 percent higher than they are today by the end of this century if Americans adopt a two-child family as their norm and 75 percent higher if they opt for the three-child family. Certainly, such income increases should help reduce the absolute if not the relative incidence of poverty in our society.

However, reasons also exist for suspecting that slower population growth could help equalize the distribution of income as well. A slower growing population tends to be an older population, and it is a reasonably well-established economic fact that people save more in the later parts of their working lives, that is after the ages of 45 or 50 or so. Accordingly, some of the economists advising the Commission have suggested that these higher savings rates may depress the rate of return on capital and correspondingly increase the share of total national income going to labor. Since wage and salary income are more important to lower than higher income groups, and conversely for returns on investments, such a shift would suggest some equalization in the distribution of income.

Even without this effect, which is admittedly quite speculative, there are other reasons for suspecting that slower population growth could imply a more equal income distribution. Specifically, more unwanted births appear to have occurred historically among poorer families. Thus, the reduction of family size from slower population growth may be greater for these lower income families. In the late 1960's, in fact, the birthrate for women in families with incomes of less than $5,000 per annum declined by over 15 percent more than for the rest of our society. The poor still have a higher birthrate than the middle classes—but the recent trends suggest that this discrepancy may be disappearing. Thus, even if family or household incomes do not go up relatively more rapidly for poor families in the future—and as we have just noted there are some reasons for suspecting that they may—the per capita income available to members of lower income families could rise relatively because their family sizes will shrink relatively rapidly.

Another economic benefit that we might derive from slower population growth would be some simplification of the structural problems we now seem to face in absorbing labor force growth. This, in turn, could reduce the intensity and frequency of certain classes of unemployment problems that now bedevil our society. Many of our present unemployment difficulties, for example, are due to a sharp rise in unemployment of teenagers and those in their early twenties who are now a larger and increasing proportion of our society because of the post-war baby boom. To illustrate what this means, consider the years 1949 and 1971 which had virtually identical overall unemployment rates, 5.9 percent. In 1971, however, the 16- to 24-year-old unemployment rate was 12.7 percent, while in 1949 it was 10.8 percent. And again, do not forget that the higher percentage rate in 1971 was applied to a larger portion of the total population than in 1949. Or, to put the matter slightly differently, if we were to calculate the ratio of unemployment rates for those 16 to 19 years of age to the unemployment rate for those 25 years and over, we would find that the annual average of this ratio was approximately three times higher in the late 1960's than it was in 1949 or 1950; indeed, this ratio even in 1960 was 3.27, while at the end of the 1960's it was almost 6.0. Slower population growth implies (though it does not guarantee for reasons that are outlined elsewhere in this Report) a steadier and *relatively* smaller flow of young people into the labor market and this in turn should simplify planning their absorption into the labor force.

It should be stressed, though, that reduced entry pressures on labor markets from slower population growth will not be realized quickly. Again, there is the

momentum created by the post-war baby boom. Thus, the level of new entrants into the labor force during the 1970's should average approximately 3.5 million or almost 700,000 persons per year more than the annual average for the 1960's. By the 1980's, however, growth in the number of labor force entrants should be nominal. What happens in the 1990's, of course, depends on what our birthrates in the 1970's actually prove to be.

Adversities, of course, can flow from slower population growth as well as advantages. For example, some economists advised the Commission that slower population growth might complicate the problem of maintaining full employment in our economy. An equal number of economists advising us said just the opposite. As just noted, slower population growth might as well simplify as complicate certain aspects of achieving full employment. So, on balance, it would seem that the Commission was correct in concluding that unemployment would not be a serious consequence of slower population growth. In essence, an unemployment problem can be solved by wise fiscal and monetary policies. Slower population growth is a very cumbersome and imperfect substitute for such wisdom.

Another difficulty of slower population growth noted by the Commission is that an older labor force may lack the vigor or flexibility to keep productivity growing at historic rates. A question also arises of whether a work force more uniformly distributed by age brackets will provide as many incentives (opportunities for promotion) as the present pyramidal age structure. In essence, a more uniform distribution of workers by age, while it may simplify certain absorption problems at the lower end of the age spectrum, may create new structural problems elsewhere in the system.

Clearly, one approach to solving such new problems is, as the Commission suggested, development of new and better programs of continuing education. The required structural adaptation may necessitate certain other changes as well, such as reinforcement of the basic market or pricing mechanisms in our economy which we depend on for the realignment of resources and economic activities.

Separate Statement of Grace Olivarez

To brush aside a separate statement on the issue of abortion on the grounds that it is based on religious or denominational "hang-ups" is to equate abortion—a matter of life and death—with simpler matters of religion such as observance of the Sabbath, dietary restrictions, abstention from coffee and alcoholic beverages, or other similar religious observances. I prefer to believe that even nonreligious persons would be concerned with the issue of life and death, even as to the unborn.

My opposition to legalized abortion is based on several concerns that touch a variety of issues, not the least of which is the effect such a law would have on millions of innocent and ill-informed persons. These concerns center around the rights of women to control their own bodies, the rights of the unborn child, the poor in our society, the safety of abortion, our country's commitment to preventive as opposed to remedial measures, and our future as a democratic society.

Rights of Women to Control Their Own Bodies

I fail to understand the argument that women have a right to control their own bodies. Control over one's body does not stem from a right, but depends on individual self-image and a sense of responsibility. I am not referring to the victim of rape or incest. *And* I am *not* referring to the poor for whom contraceptive services and techniques are not as accessible as we would want them to be.

With the recent advances in contraceptive technology, any woman who so desires is better able to control her fertility in a more effective way than has ever before been available. I accept the argument that, aside from total abstention, there is no perfect contraceptive; but no one can argue that effective contraceptives are more available now than ever before, but are effective only if used. Personal and contraceptive failures do not give women the "right" to correct or eliminate the so-called "accident" by destroying the fetus.

Advocacy by women for legalized abortion on a national scale is so anti-women's liberation and women's freedom that it flys in the face of what some of us are trying to accomplish through the women's movement, namely, equality—equality means an equal sharing of responsibilities *by* and *as* men and women.

With women already bearing the major burden for the reproductive process, men have never had it so good. Women alone must suffer the consequences of an imperfect contraceptive pill—the blood clots, severe headaches, nausea, edema, etc. Women alone endure the cramping and hemorrhaging from an intrauterine device. No man ever died from an abortion.

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A more serious question is the kind of future we all have to look forward to if men are excused either morally or legally from their responsibility for participation in the creation of life. Women should be working to bring men into the camp of responsible parenthood, a responsibility that women have had to shoulder almost alone. Perhaps in our eagerness for equality, we have, in fact, contributed to the existing irresponsible attitude some men have toward their relationship to women and their offspring. Legalized abortion will free those men from worrying about whether they should bear some responsibility for the consequences of sexual experience. In the matter of divorce where children are involved, for instance, very few men fight or even ask for custody of their children. It is customary to measure their responsibility in terms of dollars and cents, rather than in terms of affection, attention, companionship, supervision, and warmth.

And laymen are not the only ones who reflect this attitude. Blame must also be placed on church*men*, who throughout the tumult and controversy surrounding legalized abortion, have expressed their concern only as abortion affects the moral and psychological problems of women, adroitly avoiding the issue of man's responsibility to decisions connected with his role in the reproductive process.

Abortion After Rape and Incest

Pregnancy as a result of forcible rape is not common. As a rule, forcible rape involves a struggle, the effects of which can be outwardly detected. An observing parent or adult can detect the effects of such a struggle in a young girl. There is a personal responsibility for reporting such assaults. To shirk this duty under the guise of privacy, pride, or dignity is to permit abuses to go unpunished and to condemn an innocent girl to live in anguish through no fault of her own. Forcible rape should be reported as the crime that it is. Under such circumstances, the victim is given medical attention and medication that can prevent her from getting pregnant.

The key words in the definition of rape are: "without her consent." There are varying degrees of consent and resistance. To permit abortion because a woman has had a change of mind or heart after intercourse, is to deny justice to the unborn child.

Generally speaking, incest is more prevalent. Proving incest is difficult. Pregnancies resulting from incest are seldom reported or recorded as such. As in rape, abortion in this instance is punishing the child and the young girl.

Rights of the Unborn Child

In relation to the rights of the unborn child, we seem to be confused as to the meaning of human life *before* and *after* birth. The fetus does not become "a life" at a specific magic moment in the process of development. Some biologists support the foregoing and I quote from one of them:

> Everyone of the higher animals *starts life* as a single cell—the fertilized ovum. . . . The union of two such sex cells (male germ cell and female germ cell) to form a zygote constitutes the process of fertilization and *initiates the life* of a new individual." [Emphasis mine.] [Bradley M. Patten, *Foundations of Embryology*, New York: McGraw-Hill, 1964, page 2.]

Neither is it a "mass of cells," as anyone who has witnessed an abortion can testify to. Having witnessed some abortions, I would ask those in favor of abortion to visit any hospital where abortions are performed and request permission to see an aborted fetus. It will not be intact unless the abortion was performed by the saline method. Then it will be pickled, but intact.

"Wanted" and "Unwanted" Fertility

To talk about the "wanted" and the "unwanted" child smacks too much of bigotry and prejudice. Many of us have experienced the sting of being "unwanted" by certain segments of our society. Blacks were "wanted" when they could be kept in slavery. When that ceased, blacks became "unwanted"—in white suburbia, in white schools, in employment. Mexican-American (Chicano) farm laborers were "wanted" when they could be exploited by agri-business. Chicanos who fight for their constitutional rights are "unwanted" people. One usually wants objects and if they turn out to be unsatisfactory, they are returnable. How often have ethnic minorities heard the statement: "If you don't like it here, why don't you go back to where you came from?" Human beings are not returnable items. Every individual has his/her rights, not the least of which is the right to life, whether born or unborn. Those with power in our society cannot be allowed to "want" and "unwant" people at will.

The Poor in Our Society

I am not impressed nor persuaded by those who express concern for the low-income woman who may find herself carrying an unplanned pregnancy and for the future of the unplanned child who may be deprived of the benefits of a full life as a result of the parents' poverty, because the fact remains that in this affluent nation of ours, pregnant cattle and horses receive better health care than pregnant poor women.

The poor cry out for justice and equality and we respond with legalized abortion.

The Commission heard enough expert testimony to the effect that increased education and increased earnings result in lower fertility rates. In the developed countries of the world, declining fertility rates are correlated with growing prosperity, improved educational facilities and, in general, overall improvement in the standard of living.

But it is not necessary to go beyond our own borders to verify this contention. Current data indicate that the same holds true for minority groups in this country. The higher the education attained by minorities and the broader the opportunities, the lower the fertility rate.

Thus, the sincerity of our concern for population growth (because of its effect on the quality of life for all people) will be tested, if, in the face of incontrovertible facts, we move rapidly to utilize alternatives to abortion in order to reduce fertility.

The Safety of Abortion

The general public has not been given all the facts on the dangers, risks, and side effects resulting from abortion. On the contrary, we have been told that abortion is a "safe and simple" procedure, as easy as "extracting a tooth."

These are the facts. In Japan, Hungary, Yugoslavia, Sweden, England, and the United States, studies and surveys indicate that abortions are not that safe.

In Japan, for example, a survey conducted in 1969 by the Office of the Prime Minister revealed an increasing percentage of seven different complaints reported by women after abortion. These include increases in tubal pregnancies, menstrual irregularities, abdominal pain, dizziness, headaches, subsequent spontaneous miscarriage, and sterility.

Although one could argue that abdominal pain, dizziness, and headaches can be experienced by anyone, sterility, tubal pregnancy, and subsequent miscarriages are after-effects that have been reported in other countries.

From the Hungarian *Women's Journal*, April 17, 1971, No. 16, come the following statistics:

> At every 87th abortion, surgery (uterus) perforation occurs.
>
> At every 40th abortion, hemorrhaging complications set in, to such degree that the woman has to be hospitalized and again requires medical help.
>
> Every 55th abortion is followed by inflammation.

Totaled up, this means that complications can be expected at every 25th abortion; or, out of every 100,000 abortions, 4,000 patients must be hospitalized and require close medical attention. There were 12 maternal deaths out of 278,122 abortions recorded in New York after abortion became available on request.

Dr. Donald L. Hutchinson, Chief of the Department of Obstetrics and Gynecology at the University of Pittsburgh School of Medicine, was quoted in the *Los Angeles Times*, February 16, 1971, as follows:

> A survey of complications following 1,400 therapeutic abortions showed that about 10%, or 140, of the women had significant medical complications following the procedure. The most serious complication was one death which occurred during surgery made necessary by the failure of the method—injection of salt—used to induce the abortion. . . . Among 1000 women aborted by the "D and C" method (dilation and curettage) there were six that required major surgery as a result of laceration of the wall of the womb. In several cases the womb had to be removed. Among the 400 women on whom the salt solution injections were used, the most serious complications resulted from the injection of the solution into blood vessels. In three other cases there was evidence that the salt had gotten into the circulatory system and had been carried around the body. . . . in another case there were transient signs of brain damage while other cases included infections and the loss of blood through hemorrhaging, with the result that 5% of the 1,400 required blood transfusions.

Numerous other statistics on the after-effects of abortion exist, but are not included for lack of space. However, the New York experience, which is being touted as "highly successful" cannot go unchallenged.

Mr. Gordon Chase, New York City Health Services Administrator, in testimony before the Commission's hearings in New York City on September 27, 1971, reported that New York had experienced a birth decline since the advent of the abortion law. The fact is that the entire nation experienced a birth decline during the same period without legalized abortion.

The reduction in maternal deaths in New York, as reported by Mr. Chase, was credited to abortions. This is an assumption and not a proven fact. The decline in birthrates obviously, in itself, accounts for the decline in maternal mortality. Besides, maternal mortality declined throughout the country.

Recent statistics indicate that over 60 percent of abortions performed in New York were performed on out-of-state residents. Complications and deaths occurring as a result of abortions performed in New York on out-of-state women would not be recorded in New York; therefore, any New York statistics on the safety of abortion are challengeable at every level. Statistics can be categorized in different ways to support different conclusions.

Infant mortality rates are *not* reduced by killing an *unborn* child. How sad and incriminating that quality health facilities and services, denied to the poor for lack of money, are being *used* for performing abortions instead of being *utilized* for healing of the sick poor. But then, one represents a profit and the other an expense. It is all a matter of values.

Our Commitment to Preventive Measures

Although we pride ourselves on being a nation that believes in "a stitch in time saves nine," we really do not practice it. The Commission's Report includes a section on "Methods of Fertility Control" which I consider an excellent exposé of this nation's lack of commitment to the development of safer and more effective preventive measures for fertility control. If it is true that this society does not want to see abortion used as a means for population control, then I, for one, will expect an *immediate* and dramatic allocation and distribution of resources into the field of research on reproductive physiology; the development of safer, more effective, and more acceptable methods of fertility control for everyone—men and women—plus wide-scale distribution of same throughout the country. The degree of swiftness this nation employs in moving in that direction will measure the extent of its commitment to check population growth through preventive measures and not with abortion.

Our Future as a Democratic Society

> The ease with which destruction of life is advocated for those considered either socially useless or socially disturbing instead of educational or ameliorative measures may be the first danger sign of loss of creative liberty in thinking, which is the hallmark of a democratic society. [Leo Alexander, M.D., *The New England Journal of Medicine*, Vol. 241, July 14, 1949.]

> In order to persuade the citizen that he controls his destiny, that morality informs decisions and that technology is the servant rather than the driving force, it is necessary today to distort information. The ideal of informing the public has given way to trying to convince the public that forced actions are actually desirable action. . . . we are consenting to our own deepening self-destruction. [Ivan Illich, *Celebration of Awareness*, New York: Anchor Books, Doubleday & Co., Inc., page 4.]

When one considers that medical science has developed four different ways for killing a fetus, but has not yet developed a safe-for-all-to-use contraceptive, the preceding quotes cannot be dismissed as the ramblings of extremists.

I believe that, in a society that permits the life of even one individual (born or unborn) to be dependent on whether that life is "wanted" or not, all its citizens stand in danger.

As long as we continue to view abortion as a solution, we will continue to avoid facing the real issue—that abortion treats the symptom and neglects the disease. When you consider that more than half of all abortions performed in New York were performed on women under 24 years of age (and not on "those unfortunate women who could not face the prospect of still another child"), you begin to get a glimpse of one aspect of the "disease." When you consider the current rush to reform the welfare system because the cost has gotten out of hand supposedly as a result of "all those children being born to those lazy women," but subsidies

to profit-making entities suffer not one iota, one begins to get a glimpse of the disease.

When all of our people have access to the same benefits, advantages, and opportunities, abortion will not be necessary.

Separate Statements of James S. Rummonds

The Immediate Goal

I do not agree that "the policies recommended here all lead in the right directions for this nation, and generally at low costs." It seems to me that too many of the policies we have recommended, both explicitly and implicitly, are in the wrong direction and have heavy social-psychological-environmental costs associated with them. I believe that it is critically important that population growth be stabilized. To this end, I concur with Dr. Lee A. DuBridge, President Nixon's former science advisor, who wrote: "The prime task of every human institution should be to halt population growth . . . the first great challenge of our time is insuring that there are no more births than deaths. Every human institution, school, university, church, family, government, and international agency, should set this as its prime task." In addition to this concern for population stabilization, I must go beyond and say that the present size and distribution of the population in the United States is inconsistent with the traditional values of individual freedom, individual justice, and the true spirit of democracy. Thus, the population problem has a broader dimension. As stated in the introduction, the population issue raises profound questions of what people want, what they need, and what people are for. It is against this broader perspective that we have to measure the cost and direction of our population policies.

A common thread which underlies many aspects of the "population problem" is the rapid growth of urban areas of unprecedented size. The rapid rate and extent of population concentration is clearly illustrated in the growth of urban areas of one million or more people:

Year	Number of such areas	Percent of total population
1940	12	28
1960	23	38
1980	39	54
2000	44+	63

If we had wished to avoid this massive concentration of people we could have done so by avoiding, not only population growth, but economic growth. Our huge urban areas are essentially creatures of economic forces evolved for economic ends. The motivating forces have been economies of scale, specialization and division of labor, profit to the developer, and efficiency in production. Thus, there is a direct linkage between our economy and population problems.

The result of these unbridled economic forces has been the creation of an almost totally man-made living environment—built initially by economic necessity and now reflective of only a narrow portion of the full range of human needs and concerns. As we rapidly become a nation that is almost totally urban-industrial, our man-made environments will increasingly shape our individual and collective behavior. Since we are presently products of environments of our own uncertain and narrow making, it seems obvious we had best be sure we are "making man" deliberately and consonant with his highest human potentials in the future.

In earlier times, our deference to economic forces for ordering our existence was necessitated by the struggle for subsistence. The pressure for sheer physical survival in an agriculturally based economy made a virtue of pursuing one's own competitive self-interest. However, our rapidly increasing affluence makes survival concerns more and more inappropriate as goals around which to order our lives. The decreasing importance of survival concerns is reflected in the growth of our real family incomes which were roughly $2,400 in 1939, $9,400 in 1969, and are expected to be in excess of $21,000 by the year 2000. Another indication of our new-found affluence is shown by the fact that the proportion of the population in poverty has dropped from roughly 60 percent in 1929 to 12 percent today.

It seems clear, then, that a few select nations are rapidly entering a new age of human history where an increasing majority will live far beyond subsistence. However, our present values and institutions have been evolved for the express purpose of coping with the problem of marginal survival. Now, man has suddenly been deprived of his traditional economic purpose. We have been caught off guard by our success. We have only begun to realize how far we have come, let alone to think what might lie beyond. Thus, the fundamental question of our time arises: Are our contemporary values and institutions, inherited from a subsistence era, adequate or even desirable in coping with the problems and potentials of relative affluence, sophisticated technologies, and huge population agglomerations? There is

mounting evidence which suggests that our continued reliance upon traditional economic forces will lead us into a population distribution future, as well as a larger American future, that is neither wanted nor desirable.

Economic—Research data show that our larger urban areas are growing because of the momentum of natural increase and in-migration rather than because of any significant economies of scale associated with their size. It appears that an urban place of 200,000 people is as efficient as one of several million. Therefore, the economic rationale for allowing the size of our urban areas to increase is marginal at best.

Political—We value our democratic processes; yet, other things being equal, it appears to be more difficult to exercise our democratic prerogatives as the size of the political unit increases. First, as the number of citizens increases, the time that can be spent with any one of them by a government official decreases. Second, as urban size increases, there is a more than proportionate increase in public service demanded; thereby putting an even greater burden upon the democratic processes. Third, with size comes a complexity which makes it increasingly difficult for the average citizen to maintain the "relative political maturity" necessary to effectively participate in the decision-making processes. Fourth, the trend toward metropolitan government will aggravate the first three impediments to a "grass-roots" democracy.

Social—We tend to judge the "goodness" of our urban concentrations by whether or not they seem to induce such behavioral extremes as criminality, mental illness, high divorce rates, etc. The few crude studies that have been conducted have been largely inconclusive but the implicit conclusion has been: since our big cities don't produce much bad behavior, they therefore must be good places to live. However, since man is so highly adaptable, he can tolerate very undesirable environments without exhibiting pathological behavior. Clearly, reliance upon crude "tolerance" indicators to measure our social well-being will insure our living in an environment without the beauty and serenity of the countryside, without the stability and sense of community of a small town, and within the culturally desolate confines of a homogeneous suburban social layer.

Environmental—It has been conclusively documented in the Commission's research that large population agglomerations aggravate enviromental problems. This includes increasing air pollution, increasing noise pollution, decreasing access to open spaces, increasing travel time to work, increasing respiratory ailments, and adverse climatic changes. To make things worse, our research has also shown that it is oftentimes more expensive to cope with these difficulties in a larger urban environment.

Diversity—We value diversity as a precondition to freedom since freedom of choice is meaningless without something to choose from. And yet, a continuation of present distribution trends will largely narrow living choices to large urban agglomerations and will thereby eliminate a major element of diversity from our lives.

Opinion Polls—We are becoming an increasingly urban nation against the will of an absolute majority of the population. Our opinion poll survey showed that 53 percent of the population preferred a small town or country environment. Over 50 percent wanted the federal government to slow the growth of the large urban areas and over 50 percent wanted the federal government to encourage growth of smaller places. Implementation of policies consistent with these preferences would give people a greater diversity of living environments to choose from.

It seems clear, then, that we are blundering into a population distribution pattern which is unwanted by the majority of Americans. Historically, the pattern of urbanization has been a by-product of the economic imperatives of industrialization. Thus, we have trusted the control of our population distribution patterns largely to the workings of the marketplace. Only now are we learning the central weakness of the market system: The market has no inherent direction, no internal goal other than to satisfy the forces of supply and demand. With increasing abundance the market system continues to direct human activities into accustomed economic channels—yielding an increasing pro-

duction and consumption of an ever larger volume of ever less valued goods. Robert Heilbroner notes that "...the danger exists that the market system, in an environment of genuine abundance, may become an instrument which liberates man from *real* want only to enslave him to purposes for which it is increasingly difficult to find social and moral justification." What is required, then, is a realization that to solve the "population problem" requires us to create a new relationship between the economic aspects of existence and human life in its totality. Our affluence not only makes it possible but makes it imperative that we go beyond strictly economic concerns and become creative architects rather than passive pawns of our own environment. What we need as a starting point are national goals or guiding principles which go beyond a concern for mere quantity—in short a quality of life manifesto. I present the following as a suggestive listing of those individual and collective goals we might want to pursue as we become a post-industrial society:

1. *Efficiency:* Efficient production is desirable but not so desirable that in an affluent society it should take precedence over higher human values. In other words, we should be willing to accept some economic inefficiency as an inevitable but necessary price in realizing noneconomic values.

2. *Growth:* Just as population growth can reach disastrous proportions, so can economic growth. For example, if the rest of the world were consuming at our level, we would quickly exhaust available resources. Our continued high rates of growth are predicated upon continuing disparities among nations of the rest of the world. Therefore, we need to moderate our growth ethic and begin to create the society envisioned by John Stuart Mill:

> ...in which while no one is poor, no one desires to be richer, nor has any reason to fear being thrust back by the efforts of others to push themselves forward... There would be as much scope as ever for all kinds of mental culture, and moral and social progress; as much room for improving the Art of Living and much more likelihood of its being improved, when minds ceased to be engrossed by the art of getting on.

3. *Equity:* Elimination of poverty in an affluent society through overall increases in real income is too slow and unjust. Further, large disparities in income will only serve to encourage further demands for economic growth as those less advantaged note their relative rather than absolute income position. A reduction in inequity is a necessary precondition to justice as well as to the gradual attainment of a dynamic, steady state economy.

4. *Democracy:* Big business requires big government to control, big unions to bargain effectively, and big cities as productive economic mechanisms. In each case, the individual comes to feel that he just "can't make a difference" as his political power is swamped by huge, complex organizations. Therefore, if we prize our democratic processes, we had best be willing to seek a population level and design our institutions so that they are compatible with democracy.

5. *Environment:* We can no longer assume the arrogant role of mastery over nature; rather, we must learn to live in balance and harmony with our environment. This means we must be sensitive to the possibility of world wide depletion of resources and to the domestic aspects of environmental degradation—particularly in our large urban areas.

6. *Life Style:* Finally, and perhaps most important, we need to insure a physical environment that is conducive to a variety of life styles. Underlying this is a recognition of the supremacy of the individual. This was well stated by the Eisenhower Commission on National Goals: "The first national goal to be pursued . . . should be the development of each individual to his fullest potential. . . . Self-fulfillment is placed at the summit. . . . All other goods are relegated to lower orders of priority . . ." But what conditions are most conducive to self-fulfillment? Do the expressed and implied policies in this report enhance the creation of a physical and social environment compatible with human actualization? Too often they do not. The following points will briefly illustrate why.

> *Work*—We have become a very productive society but at great expense to the fulfillment to be gained through our work. Most people are now alienated from their work, viewing it only as a means of acquiring the money to satisfy other needs. The excessive specialization and division of labor deprives the worker of a sense of completion and purpose in his productive process.
>
> *Nature*—Our man-made environments have isolated man from his historical habitat and thus deprived him of an important life perspective. Whereas the agrarian environment forced a realization of man's finitude in relation to the ecologic totality of the earth,

the urban environment allows an arrogance of power since man is living in a world of his own making. Seldom is there a sense that man has not created all. The hubris engendered by this anthropocentric environmental perspective may help to explain our current despoliation and disregard for that seemingly outside of man's created domain.

Community—In our search for personal identity through goods acquired and occupational status achieved we have been willing to move to wherever there were the greatest economic opportunities. These high rates of geographic mobility in search of social status have destroyed our sense of community.

Family—With the transition to an urban-industrial economy we have had to forsake the extended family since it was no longer an economically productive mechanism. With its economic reason to exist undermined, the social rationale was not insufficient to insure its continuity. With further industrialization came specialized demands for education and the traditional educational role of the family was subsequently lost as well. Now, with further economic "progress" we have a developing interest in child-care centers for working mothers. Although I can grant the pragmatic desirability of such institutions within an urban-industrial context, it saddens me to think that we may soon see the day when the last significant role of the family—the love and warmth of the mother—will soon disappear just as did the economic and educational roles.

In conclusion, as a rural-agrarian society, we had many of the life style elements that we now look for in vain: our sense of belonging to, and finding identity in, the family and community, knowing that there was understanding, concern, and compassion deep felt by our peers and neighbors, and being able to exert influence on the political and economic institutions of our community and society. These parts of our lives and more are being lost in our passion for affluence and in the overwhelming surge of sheer numbers of people. Surely it is time for those in control of our political and economic institutions, our leaders, to begin to create conditions wherein the highest qualities of human existence can more fully come to fruition.

The Economy

The Commission asks, what effect will slowing population growth have on the health of the economy? It concludes, with minor exceptions, that slowing population growth will not be detrimental to the economic interests of the American people. The Commission does not ask what effect the American economy has on the noneconomic interests and values of the people of this country and the world; a world increasingly characterized by overcrowding, resource depletion, ecological imbalances, and individual alienation. Put another way, is an economic system predicated on the principles of productivity and efficiency and characterized by ever-increasing concentration of the ownership of the means of production, capable of responding to the individual's need for security, purpose, and dignity? Is an economic system motivated by profit and oriented to mass consumption as an end in itself capable of guarding the values of individuality, family, and community?

While the Commission is correct in concluding that slowing population growth will not necessarily prejudice economic interests, there is considerable evidence to suggest that the system itself is destructive of a broad range of values closely held by the American people, including the job security of significant numbers of people.

Unemployment will continue to be a difficult problem for the next several years. The reason is that the rate of increase in the supply of human resources will be high, and continuing competitive pressure for efficiency will reduce demand for labor per unit of work output.

The best predictor of the increase in the labor supply each year is the number of people born about 20 years earlier. In 1950, about 3.65 million people were born in the United States, and these people entered labor force pool about 20 years later, in 1970. By 1955, births had increased to 4.13 million, so the labor force will have to accommodate more new laborers in 1975 than in 1970 if the unemployment rate is to stay constant at its present level. By 1957, births had reached 4.33, so by 1977, the labor force will have to accommodate an increase of almost 20 percent over the number of new workers as in 1970.

The problem of absorbing this increasing number of new workers into the labor force each year will be rendered particularly difficult by the strong pressure for efficiency. Each year, the work output per worker is expected to increase. This means that the number of

workers required for a given amount of work is constantly dropping. Thus, at the very period in the nation's history when a great many new jobs are required, the pressure for efficiency is reducing the demand for new workers.

The magnitude of the drop in demand for workers over the last several years is quite surprising.

For example, in 1950, scheduled air carriers employed 8.1 personnel for every million revenue passenger miles of transportation provided. By 1968, only 2.6 personnel were employed to provide the same amount of transportation.

From 1950 to 1968, the number of men employed in the oil and gas industries to deliver one quadrillion British Thermal Units of energy dropped from 28.4 to 11.5.

From 1950 to 1969, the number of people employed on farms to deliver 100 units of farm output decreased from 11.6 to 3.8.

This tremendous reduction in number of workers required per unit of work delivered in all existing industries and businesses means that there must be a tremendous increase in the number of new enterprises in the next 10 years if unemployment is to be kept at a level of six percent of the labor force.

The problem is compounded, because not only will there be continuing reduction in the number of workers per unit work output, but, in addition, there are a number of major industries in which there will be a reduction in the amount of work output, because of market saturation.

A particularly striking example is the aerospace industry. In 1970, the total number of jet aircraft used by all scheduled airlines in the world was only about 5,000 Boeing 707 equivalents. In 1972, at least seven major new models of large jet aircraft are being manufactured in several countries. The number of copies of these models that would have to be produced in order for the manufacturers to yield to a reasonable return on invested capital is very large. In fact, the world jet fleet would have to be at least doubled from its present size. Since load factors (percent of seats filled) in commercial scheduled airlines had dropped to less than 50 percent in the early 1970's, and domestic demand for seats only increased two percent in 1971, it is difficult to see how demand for new models of aircraft can hold up. Consequently, there will probably be still more layoffs in the aerospace industry in the next few years. This could have an important effect on the entire economy, for two reasons. First, the industry uses about 60,000 workers for each new model of aircraft manufactured; this is about one-tenth of one percent of the entire labor force. Second, jet aircraft is the most important single export item of the nation. Slackening of sales would intensify an already deteriorating balance of trade situation.

These problems are compounded by the prospect of increased costs resulting from environmental deterioration and escalating demands on our social and political institutions. What this suggests is that demographic trends, like environmental pollution, impose costs that the market economy traditionally has externalized or failed to take into consideration. That the present economic system is no longer representative of the beneficial interests of the American people and in fact, in conflict with the material conditions of the modern world, should not be discounted.

Government

The Commission has asked: "Can government adapt to the new realities and fragility of our existence as the pace of our lives accelerates, the world grows more crowded, technology multiplies life's complexities, and the environment is increasingly threatened?" It concludes, ". . .slowing down the rate of population growth would ease the problems facing government in the years ahead: . . ." This is not a particularly responsive answer to the question posed. Perhaps the Commission did not intend otherwise.

Government has been defined as, "that form of fundamental rules and principles by which a nation or state is governed, or by which individual members of a body politic are to regulate their social action." Accordingly, the question posed by the Commission cannot be answered by statistical projections or cost benefit analysis. Rather, we must ask if the rules and principles of government and social behavior are adequate to meet both the just demands of the people and the dictates of demographic and ecological imperatives. This question can profitably be viewed as three distinct inquiries.

First, what are the rules and principles of government in the United States; or, in other words, what is government for. One response to this question has been given by Arthur S. Miller of the George Washington University Law faculty and a contributor to the Commission's research project: "The raw material of modern government is business, taxation, utility regulation, agricultural control, labor relations, housing, banking and finance, control of the security market—all our major domestic issues—are phases of a single central problem: namely, the interplay of economic enterprise

in government. . ." While it cannot be denied that modern government undertakes programs to accomplish noneconomic objectives, it can readily be seen that there is considerable truth in the observation that, "the business of government is business." Indeed, the dominant analytical perspective taken throughout this Report supports a predominantly economic interpretation of the role of government.

The second question is to what ends are the rules and principles of government applied. This can be answered in a number of ways. For example, the ends can be equated with "values." It is generally agreed that one of the primary *stated* goals or values of government in the United States is the promotion and enhancement of individual freedom for all the people. Thus, the "government" pursues the goal of "freedom" through the vehicle of the "free market" and the maintenance of competitive economic conditions. Fundamental to this particular notion of "freedom" is a reliance on the "invisible hand" or classical laissez-faire economics.

Another end or goal of the rules and principles of government can be ascertained by analyzing the distribution of wealth in society. By this standard, the end of "government" can reasonably be understood as seeking to maximize the satisfactions of the dominant forces in society, that is, the owners of the means of production. However, it has been forceably argued by the sociologist Max Weber that freedom and wealth are, in fact, one in the same:

> The exact extent to which the total amount of 'freedom' within a given legal community is actually increased depends entirely upon the concrete economic order and specifically on property distribution. In no case can it be simply deduced from the content of the law.

The final question is, can the present political economy (government) of the United States cope with the demands presently being placed upon it. A. E. Keir Nash, formerly a director of research and now a consultant for the Commission, responded to this question as follows:

> There is good reason to doubt the capacity of the American governmental system to accommodate a third 100 million citizens in the final decades of the 20th century. There are strong grounds for doubting the ability of the government both to maintain political order and to attain social justice among a citizenry of 300 million.

Dr. Nash goes on to note two fundamental failures of American government. First, is an historical failure to fulfill its basic promises of freedom and equality. Second, is the failure of government, "to shift government actions—so as to make them appropriate to the increasingly crowded world in which we live."

> Legislative and executive policymaking continues largely to be based upon log-rolling and incremental solutions to problems in the society and the economy which are not genuine solutions at all. Such pseudo-problem-solving may work respectably when the basic structures of the economy, the society and the environment are not in flux. They may be admirable in a largely empty and unsettled country, half slave and half free. Yet they are wholly unsuited to the problems which confront Americans today. The politics of yesterday is simply not suited to the needs of tomorrow.

The Commission chose to reject the evidence militating toward this conclusion. I cannot.

Separate Statement of Howard D. Samuel

Although I fully share the goals of ending discrimination and providing equal opportunity for women, I disagree that passage of the Equal Rights Amendment would be a useful step in that direction. On the one hand, the Equal Rights Amendment would accomplish very little for women; what is needed is a specific body of legislation, federal and state, to end discriminatory practices and open up opportunity. On the other hand, the Equal Rights Amendment would have a destructive effect in that it would render invalid present state laws protecting women—particularly women workers—against certain kinds of injustice and hardship. For this reason, I do not support the recommendation endorsing the Equal Rights Amendment.

Separate Statement of George D. Woods

I believe the Commission should leave decisions on the amounts of funds necessary to the proper authorities. Such amounts may be either lesser or greater than those recommended in these sections.

Resources and Man

A STUDY AND RECOMMENDATIONS

by the Committee on Resources and Man
of the Division of Earth Sciences
NATIONAL ACADEMY OF SCIENCES—
NATIONAL RESEARCH COUNCIL

with the cooperation
of the Division of Biology and Agriculture

W. H. FREEMAN AND COMPANY
San Francisco

Introduction and Recommendations

"There are three imperatives: to reduce war to a minimum; to stabilize human population; and to prevent the progressive destruction of the earth's irreplaceable resources."

—Sir Macfarlane Burnet, 1966[1]

This book is about problems that confront man in seeking a durable accommodation with his natural resources. Concepts of resources, to be sure, change from time to time and from place to place, but the general notion is always of something necessary or useful, like food, clean air and water, and materials that skilled hands and discerning minds can turn to the improvement of the human lot. Various aspects of man's relation to his resources are considered in the chapters that follow. Here we state the main features of our study.

The central question is: can man approach a kind of dynamic equilibrium with his environment so as to avert destructive imbalances? Ultimately this question involves the entire globe and the distant future. We have chosen, however, to concentrate on material resources other than air and water, and on North America—although with global cognizance and in ecological context. As for time scale, we have tried to look well beyond the year 2000, but to keep the shorter term in view. In order to focus on the issues that seem to us

[1] In "Ecology and the Appreciation of Life," The Boyer Lectures, Australian Broadcasting Comm., Ambassador Press, Sydney, p. 29.

to block a general appreciation of the importance and gravity of resource problems, and in the interests of brevity, we have also left out much detail that might have been included in a technical report. Thus we often find ourselves dealing with methods of making estimates, and with the limitations of those methods, rather than with the commonly uncertain estimates and projections themselves. It is especially in this combination of analysis of underlying assumptions, ecological orientation, broad scope, long-range view, and relative brevity that our report differs from previous resource assessments.

In preliminary discussions we asked particularly what resources are vital to our well-being and economy now, which are likely to be vital in the future, what substitutions and technological innovations might modify resource priorities, and what limits are placed on population and material growth by resource availability. We also considered the consequences of limited supply of resources and of varying social and economic concepts that affect their use and adequacy. Such considerations bring out a major difficulty in the planning process: a series of separate decisions, each individually justifiable, can, in the aggregate, lead to results which, had they been foreseen, might have been avoided. To a degree, therefore, we have attempted to view the management of many resources simultaneously and under alternative assumptions about sociopolitical response and technological evolution, but our attempts indicate that far more extensive analysis of alternatives will be needed to develop comprehensive resource policies of long-term validity.

A prime conclusion of ecology is that species whose populations exceed or approach too closely the carrying capacity of resources in the space occupied undergo reduction. Such reductions are often severe and may lead to extinction because of disease, pestilence, predation, or aggressive competitors. Although it is true that man has repeatedly succeeded in increasing both the space he occupies and its carrying capacity, and that he will continue to do so, it is also clear that both the occupiable space and its carrying capacity have finite limits which he can approach only at great peril.

It is essential, therefore, that we carefully assess and continually reassess these limits, and that we take steps to assure that future generations, as well as people now living, will have the resources necessary for a satisfying life. These resources, moreover, must be so distributed as to exclude catastrophe as a factor in limiting population density. As Marston Bates stresses in Chapter 1, few species of animals ever really multiply to the absolute limit of their food supply under natural conditions; other controlling factors intervene, often of the sort that humans would call psychic or psychosomatic. Man also must adapt to his ecosystem—to his physical environment and its biological components. We cannot long operate as a force apart from it, for we are not. Above all, we must be wary of man's tendency to reduce the variety of components in his ecosystem, for this increases susceptibility to adverse change.

Many people outside the Atlantic community of nations are now threat-

ened with poverty and famine as a result of population increases that locally exceed the carrying capacity of the land. To a greater or lesser degree the same potential danger threatens all people, as Malthus first clearly recognized in 1798. Wishful thinking does not banish the problem. Harrison Brown asked in 1954[2]: "Is betterment of the situation really within the realm of possibility? And if betterment is possible, at what level can the greatly increased numbers be supported? Lastly are the earth's resources sufficient to meet the enhanced demand?" The same questions haunt us with increasing intensity—an intensity as yet almost unrelieved by significant decreases in rates of population growth. By average American standards, two thirds of the world's people are still ill-fed, ill-housed, and ill-clothed, including many in North America. What can we in North America do to aid our own underprivileged, to meet the population increases that will yet precede real population control, and to help the rest of the world?

The answer is that much can be done, given sufficient effort in resource management. But other dangers arise. The quality of life, which we equate with flexibility of choices and freedom of action, is threatened by the demands of an expanding economy and population. This happens in three principal ways: (1) through the restrictive and harmful effects of pollution; (2) through the increasing frequency and complexity of unconstructive but unavoidable human contacts; and (3) through the necessary increase of regulatory measures—all in consequence of increasing use of and competition for resources, space, recreation, transportation, housing, and even educational facilities.

Thus, in addition to energy, mineral, and food resources, the quantity and quality of the human resource itself are critical components of the equation. As John D. Chapman brings out in Chapter 2, man is not only a part of his ecosystem, he is the most powerful influence in it. He is simultaneously its potentially most precious resource and its most serious threat. The gains from technological development must always be balanced in as much detail as possible against its costs. Man's own best interests plead for a more generous attitude toward the rest of nature and for less materialistic measures of well-being and success—especially in the developed countries. Such changes in attitude would make it easier to bring about dynamically balanced relations between the need for materials and the quantity available on the one hand and the quality of life and quantity of consumers on the other.

The growing quantity of people is a key factor whose future dimensions we should like to be able to estimate. Problems involved in that estimate are discussed by Nathan Keyfitz in Chapter 3. Only two things seem certain: there are going to be more people in the future and they will live in denser aggregates. The number of people to be accommodated by the end of the century, moreover, adds a new dimension to current crises. To accommodate these

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[2] *The Challenge of Man's Future*, Viking Press, New York, p. 61.

populations, the developed world will require, by the year 2000, additional urban facilities equivalent to all of those already in existence, and correspondingly more for the underdeveloped world. This calls for an entirely different view of our cities and their resource requirements than if we think only of ameliorating specific crises step by step as they arise. Complete urban renovation, the creation of new and better living clusters throughout the country, and better and more diversified use of suburban and rural space are a big order; but it is an order that is practicable, necessary, and urgent. There is no simple "best solution." A variety of solutions must be tried, and for all of them the resource component (including clean air and water) will be central.

Somehow we must manage by the year 2000 to support a population increase in the United States from the present 200 million people to between 300 million and 340 million, and an increase in world population from the now more than 3.5 billion people to between 6 billion and 7 billion—an increasing proportion of them in cities. Failure to support that population increase would have unacceptable consequences. Population control, essential in the long run, cannot come soon enough to eliminate the challenge. To stabilize populations requires that the birth rate not exceed 14 live births per year per thousand people at the 70-year life expectancy sought as a goal for all. Only Hungary, Japan, and Bulgaria currently have such a low birth rate. This shows that a stabilized population can be achieved, but as Kingsley Davis has emphasized,[3] the inadequate measures that now pass for population control at best eliminate only unwanted births. Birth rates over most of the world cannot be brought to control levels by presently accepted measures. Steps must be taken to realize a zero rate of population increase as the ultimate goal. In the meanwhile, the increasing number of people to be accommodated will severely tax the capacity of the human ecosystem.

Nutrition is the first essential; yet problems of distribution, of local failure to exploit potentialities, and with social customs that dictate what food is acceptable are more immediately urgent than the problem of quantity of food available or producible on a global scale. If present world food production could be evenly rationed, there would be enough to satisfy both energy (calories) and protein requirements for everyone—although with drastic reductions for the now affluent. All-out effort, including the provision of ample fertilizer, and genetic, ecological, and chemical research, could probably quadruple production from the lands and double production from the waters by the end of the century. If such increased production were evenly distributed, it could keep up with population growth expected during the same time and even permit some improvement of diet. But will such all-out effort be started and sustained?

The probable ultimate increase in production of food from the sea on a

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[3] *Science*, 1957, vol. 158, p. 730.

sustained basis is not likely to be much more than about two and one-half times the present annual production of 60 million metric tons of fish, containing 12 million tons of usable protein—an estimate that emerges from William E. Ricker's analysis of marine production in Chapter 5. An increase to as much as four times the present production is unlikely. Perhaps the most important thing to bear in mind about aquatic food products, however, is that although they are an excellent source of protein they are a poor source of calories. Only the land can supply calories in adequate quantity for the needs anticipated, an eventual increase of possibly eight times the present land production being foreseen by Sterling B. Hendricks in Chapter 4. To attain this, however, will call for maximum increases in productivity of existing lands, cultivation of all potentially arable lands, new crops, the use of more vegetable and less animal protein, continued risky use of ever-new but hopefully degradable biocides, chemical or microbiological synthesis of foods, and other innovations.

Foreseeable increases in food supplies over the long term, therefore, are not likely to exceed about nine times the amount now available. That approaches a limit that seems to place the earth's ultimate carrying capacity at about 30 billion people, *at a level of chronic near-starvation for the great majority* (and with massive immigration to the now less densely populated lands)! A world population of 30 billion is only slightly more than three doublings from the present one, which is now increasing at a doubling time of about 35 years. At this rate, there could be 30 billion people by about 2075 in the absence of controls beyond those now in effect. Hopeful allowance for such controls (Chapter 3) suggests that populations *may* level off not far above 10 billion people by about 2050—and that is close to (if not above) the maximum that an *intensively managed* world might hope to support with some degree of comfort and individual choice, as we estimate such immeasurables. If, in fulfillment of their rising expectations, all people are to be more than merely adequately nourished, effort must be made to stabilize populations at a world total much lower than 10 billion. Indeed it is our judgment that a human population less than the present one would offer the best hope for comfortable living for our descendants, long duration for the species, and the preservation of environmental quality.

Man must also look with equal urgency to his nonrenewable resources—to mineral fuels, to metals, to chemicals, and to construction materials. These are the heritage of all mankind. Their overconsumption or waste for the temporary benefit of the few who currently possess the capability to exploit them cannot be tolerated.

The nonfuel mineral resources are very unequally distributed, both as to location and as to grade. No nation is self-sufficient in all of them, even in the short term. The ultimate resources of major industrial metals such as iron and aluminum, to be sure, are very large, for their availability depends mainly on

improvements in recovery methods. But true shortages exist or threaten for many substances that are considered essential for current industrial society: mercury, tin, tungsten, and helium for example. Known and now-prospective reserves of these substances will be nearly exhausted by the end of this century or early in the next, and new sources or substitutes to satisfy even these relatively near-term needs will have to be found. It is not true, although it is widely believed, that tonnages of metalliferous rock generally increase geometrically with arithmetic decrease in grade. Much of Chapter 6, by Thomas S. Lovering, is devoted to showing why this is an invalid generalization that encourages a dangerous complacency. Neither is abundant cheap energy a panacea for waning resources. Innovation of many kinds will be needed—in methods of finding ore, in mining, in extraction of metals, in substitution, in transportation, and in conservation and waste disposal. For all reusable materials in short supply, appropriate laws or codes restructuring economic incentives could facilitate conservative recovery, more efficient use, and reuse, thereby appreciably extending now foreseeable commodity lifetimes.

It is not certain whether, in the next century or two, further industrial development based on mineral resources will be foreclosed by limitations of supply. The biggest unknowns are population and rates of consumption. It is self-evident, however, that the exponential increases in demand that have long prevailed cannot be satisfied indefinitely. If population and demand level off at some reasonable plateau, and if resources are used wisely, industrial society can endure for centuries or perhaps millenia. But technological and economic brilliance alone cannot create the essential raw materials whose enhancement in value through beneficiation, fabrication, and exchange constitutes the basic material fabric of such a society.

The mineral and chemical resources of the sea (Chapter 7) will increasingly supplement those from the land—but only for a few of the many commodities we need. Information on which to base a durable assessment of such resources is not now available, but it can be expected to improve as research and exploration increase. Although ocean waters cover two-thirds of the earth, what little is known about the composition and probable history of the three quarters of the sea bottom that lies beyond the continental rises does not support the popular belief that this region harbors great mineral wealth. Beneath a thin veneer of young sediments, the floor of the ocean basins appears to consist of young basaltic rocks, only sparsely metalliferous and in constant slow motion toward and beneath the continents. Much more promising are the potentialities of the submerged parts of the continents—of oil from the sediments of the continental shelves, slopes, and rises and of mineral placers near the coast. Seawater is also an important source of some useful elements and salts, but only for a few of those needed.

On the one hand, therefore, mineral and mineral-fuel production from the sea are certainly worth going after and will increasingly help to meet needs

95-852 O - 73 - 41

and shortages in certain commodities. On the other hand, there is little basis for assuming that many marine mineral and chemical resources are of large usable volume or feasible recoverability or that for many essential substances there are any marine resources at all. The roughly $4 billion 1964 world production of offshore mineral resources shows clearly that profits are to be had from the sea. Whether offshore minerals will provide an adequate supplement to the mineral resources of the lands in the needed variety of products is quite another matter.

Finally, energy resources are considered in Chapter 8, by M. King Hubbert. Known or potential energy resources include power from flowing waters, tidal power, geothermal power, solar energy, and mineral fuels. Of these, conventional water power, if fully developed, would be about equal to that currently generated from fossil fuels. Important as they could be, however, especially in presently underdeveloped parts of the southern hemisphere, conventional sources of water power are erratically distributed, and reservoirs silt up. Tidal power and geothermal power are only locally available and neither represents a potential energy supply of more than about 2 percent of that available from water power. Solar energy, although daily renewable and enormous in amount, offers little promise as a major source of industrial power because of the difficulty of achieving the essential concentration and continuity of energy and because of the large quantities of metals and other materials that would be required for solar energy plants of significant capacity.

Sources of power for the future are to be sought among the mineral fuels, and above all in nuclear energy. It will take only another 50 years or so to use up the great bulk of the world's initial supply of recoverable petroleum liquids and natural gas! Recoverable liquid fuels from tar sands and oil shales, although their estimates are very uncertain, might supplement conventional petroleum fuels sufficiently to extend the total lifetime of the petroleum family of fuels as an important source of industrial energy to as much as a century from now. The remaining effective lifetime for coal, if used as the principal source of energy at expected increased demands, would be no more than two or three centuries (although the normal tapering-off in use of a diminishing resource will assure its continued production for perhaps another 500 years from the present). Moreover, we cannot simultaneously use the fossil fuels for fuels, petrochemicals, synthetic polymers, and bacterial conversion to food without going through them even more rapidly. A major side benefit from converting to nuclear energy as our main energy source, therefore, could be the adoption of measures to conserve the fossil fuels for other useful purposes and for *essential* liquid fuels.

Nuclear power from naturally fissionable uranium-235 and from fissionable isotopes obtained by neutron irradiation of uranium-238 and thorium-232 is potentially orders of magnitude larger than that obtainable from all the

fossil fuels combined. The supply of uranium-235 from high-grade ores, however, is severely limited, and the production of nuclear power at a cost competitive with fossil fuels or water power, using the present light-water converter reactors and uranium-235 as the principal energy source can be sustained for only a few decades.

If the potential of nuclear power based on the fission reaction is to be realized, therefore, this can be accomplished only by an early replacement of the present light-water reactors (which can use only about 1 percent of natural uranium) by fully breeding reactors capable of consuming the entire amount of natural uranium or thorium supplied to them.

Controlled fusion has not yet been achieved and may never be. Should it be, however, the energy obtainable from the deuterium contained in 30 cubic kilometers of seawater would be about equal to that of the earth's initial supply of fossil fuels!

On a long-term basis, an achievement no less essential than a practical nuclear-energy economy itself must be the development of an adequate system of safe disposal of nuclear-fission wastes. Much progress has been made within the last decade by the U.S. Atomic Energy Commission in the processing and safe underground disposal of low-volume, high-level wastes. Less satisfactory progress has been made in the handling of the voluminous low-level wastes and solid trash. In fact, for primarily economic reasons, practices are still prevalent at most Atomic Energy Commission installations with respect to these latter categories of waste that on the present scale of operations are barely tolerable, but which would become intolerable with much increase in the use of nuclear power.

To summarize this study, Chapters 1 and 2 of our book pose the problem: since resources are finite, then, as population increases, the ratio of resources to man must eventually fall to an unacceptable level. This is the crux of the Malthusian dilemma, often evaded but never invalidated. Chapter 3 considers the possibility of a final evasion of this dilemma by population control. Chapters 4 through 8 consider the possibility of escape by increasing resources of food, minerals, and energy, each chapter dealing with essential but not coordinate aspects of the problem. The inescapable central conclusion is that both population control and better resource management are mandatory and should be effected with as little delay as possible.

We must add an elaboration, however. Studies of animal populations suggest that environmental factors other than simple limitation of material resources may act in unexpected ways to limit populations before theoretical maxima are reached. To consider whether the earth might support three more doublings of the human population is probably to consider a purely hypothetical situation. It seems more likely that further crowding, the necessary social and governmental restrictions that accompany dense settlement, and certain kinds of boredom resulting from isolation from nature in an immense,

uniform, secular society may prove so depressing to the human spirit or so destructive of coherent social organization that no such population size will ever be reached. Current urban problems are perhaps premonitory of what can come in the absence of more effective attention to the broader problems of resources and man. In attempting to deal with such problems we would do well to consider the basic causes as well as the symptoms. To delay progress toward full self-regulation of population size is to play "Russian roulette" with the future of man.

More specific recommendations arising from this study will be found in the following section. The words we would choose to express the essence of our hopes for the future, however, have already been written: "Our goal should be not to conquer nature but to live in harmony with it."[4]

Recommendations

This study points to the need for better information on which to base an improved assessment, not only of the natural resources of the nation and the earth, but also of the likely future demands on them and of their deeper societal implications. Although no real physical *terra incognita* remains today, we have much to learn about what we have, how to estimate it, and how to manage it in the best interests of man and nature. The Malthusian limits are more likely to be extended by recognizing their validity and doing something about them than by uninformed ridicule. We recommend below,[5] therefore, some of the steps that should be taken by the United States to enhance the prospects of an ample world for all.

These recommendations are not intended to be comprehensive or rigorously systematic; rather, their aim is to highlight the steps that most deserve to be initiated or pursued more vigorously by reason of special relevance, timeliness, or high potential value to society. They are arranged, according to their main aspects, under four broad categories: (1) Early Action, (2) Policy, (3) Research, and (4) Organization. Listed after each recommendation, as appropriate, are the chapters in which substantiating discussion is to be found. Where no specific chapter reference is given, the recommendation emerged from the study as a whole, including discussions at our several exploratory conferences.

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[4] Roger Revelle, 1967, p. 1 of "Introduction," in United States Participation in the International Biological Program, U.S. National Committee for the I.B.P., Rep. no. 2.

[5] Members of the Committee who are not citizens of the United States have disqualified themselves from participating in recommendations regarding specific actions of the U.S. Government. They concur in principle, however, with the recommendations made here.

EARLY ACTION

The Committee on Resources and Man urges early action to implement the following recommendations:

1. *That detailed assessment of the actual and potential agricultural and forest lands of the world and their classification into best-use categories be undertaken, together with increased technical help to the farmers of the world.* Many parts of the world are not as productive as they could be, and others are unproductive for poorly understood reasons. Special problems arise in the tropics (Recommendation 20), where the United States should establish a laboratory and field organization for tropical agriculture. This recommendation calls for action by the Department of Agriculture, with the collaboration of the State Department and the United Nations. *Chapter 4.*

2. *That there be a large increase in the effort directed toward a comprehensive geochemical census of the crustal rocks of the nation, the continent, and the earth, including those parts beneath the sea.* Better knowledge than we have of the distribution and abundances of the elements is needed to define the world's metallogenic provinces, to develop new exploration techniques, to identify substitutes for materials in short supply, and to designate substances with a variety of physical and chemical properties for consideration in the design of new products. A geochemical census, of course, must be done in the framework of adequate geological mapping, sequence control, and investigations into a variety of geological processes. Such studies ordinarily need lead times of a decade or more before application, but their results can be useful for many decades. The existing program of the U.S. Geological Survey should be intensified and enlarged, and new activities should be started. Global coordination calls for suitable international structures, with the Geological Survey, the Bureau of Mines, and university groups playing major operational roles. *Chapters 6, 7.*

3. *That the present Helium Conservation Program of the Department of the Interior be reevaluated.* Helium is unique in its combination of unusual properties and critical uses. It is essential for cryogenics, superconductivity, cooling of nuclear reactors, exploration of the seabed, and the space program. According to available estimates it is in short supply, yet it continues to be wasted in the combustion of natural gases. Its recovery from these gases and conservation for the future is feasible and is already being done on a limited scale. The Helium Conservation Program should be carefully reevaluated to determine if it can meet helium needs beyond the early part of the 21st century. If such evaluation leaves any question at all about the adequacy of the

program, the program should be extended without delay to apply to lower concentrations of helium and more natural gas fields. *Chapters 6, 8.*

4. *That a new and more rigorous monitoring system for radioactive waste disposal be instituted at Atomic Energy Commission and other installations where such wastes are now or may later be produced.* Such a system must be independent of the agencies and organizations that generate such wastes, analogous to a system of financial auditing. Reports emanating from the responsible group charged with the operation of this monitoring system should be made public so that every citizen will know what is being done to protect his safety as well as what needs to be done that is not being done. The financial cost of maintaining such a system and responding to necessary safety measures must not be a limiting factor in achieving the best possible surveillance and action program. *Chapter 8.*

POLICY

The Committee on Resources and Man presents the following recommendations for implementation as matters of national policy:

General Policy

5. *That efforts to limit population increase in the nation and the world be intensified by whatever means are practicable, working toward a goal of zero rate of growth by the end of the century.* Healthy and intelligent people are man's greatest resource. If limitation of population is not eventually achieved at some reasonable level, moreover, food and other resources will surely be inadequate. With limitation of populations the objective can be shifted from combating starvation and want to the improvement of the human resource and its level of living. Although this recommendation is by no means novel, it emerges again from our study, and particularly from Chapter 2, that population control is the absolute primary essential without which all other efforts are nullified. Our Departments of State and of Health, Education, and Welfare should adopt the goal of real population *control* both in North America and throughout the world. Ultimately this implies that the community and society as a whole, and not only the parents, must have a say about the number of children a couple may have. This will require profound modification of current attitudes toward parenthood. *Chapter 2.*

6. *That innovation of all kinds to stretch out, renew, enlarge, or substitute for the components of the world's mineral-resource base, be encouraged.* An ample

energy base, more efficient long-distance transfer of energy, and better transport systems can make available the ores of remote places. Research in the properties, purification, extraction, and fabrication of metals or even non-metals not now used, or used for other purposes, can lead to substitution. New synthetic products made from abundant raw materials should be sought as substitutes for rare or depleting natural commodities. Clad metals (as in present "silver" coinage) can stretch out rare materials and generate new combinations of properties. Man's resources may be limited but his imagination in their use and conservation need not be. Much work of this sort can and should be done under the auspices of the Departments of the Interior and Commerce. The need for a constant flow of fresh ideas and new viewpoints, however, will best be met by greater involvement of university groups through sponsored research. Such sponsorship should come not only from mission-oriented agencies, but also from the National Science Foundation in pursuance of its new charter to extend its support of selected areas of applied research.

7. *That continuing systematic programs and structures be organized to promote more pervasive interaction among the environmental sciences, and between them and the behavioral sciences, technology, and the strictly physical sciences.* We need more schools and institutes of environmental studies where ecologists, hydrologists, meteorologists, oceanographers, geographers, and geologists will work closely together, and with scholars and practitioners from other fields. Such organizations might serve as the cores of new "urban grant" universities intended to nucleate new urban centers, thereby also helping to create the scientific manpower to support the environmental and resource programs needed. More interaction among governmental agencies concerned with different parts of the environment should also be generated, as well as among them and other parts of the scientific and governmental communities. These goals should be explicitly supported by the National Science Foundation and the Department of Health, Education, and Welfare. Given the interest the National Science Foundation is now taking in the environmental, applied, and behavioral sciences, institutional structures wherein all could focus simultaneously and in concert on our deteriorating human ecosystem could be a major step toward its improvement.

8. *That formulation of natural resource policies for the nation, the continent, and the world be vigorously sought—through whatever government structures and bilateral and multilateral covenants may best serve such purposes.* Resources are not a one-state or one-country affair; they concern the whole world and all people. The international character of the formulation of resource policy clearly requires the participation of the Department of State, which must develop the necessary mechanisms to work in close conjunction

with the Departments of the Interior, Agriculture, and Commerce, as well as with other concerned groups (e.g., Recommendation 26).

Policy with Regard to Sources of Food

9. *That the efficiency and capacity of agricultural productivity, both in the United States and abroad be increased to the maximum levels possible.* This is necessary not only to assure national food reserves, but also to help those countries in need. Overproduction, as well as underproduction, of perishable products must be controlled, for it is evidence of poor national management and vitiates the improvement of farm production and management. The Department of Agriculture has been working in these directions for a long time, in collaboration with the Department of State and the United Nations. The effort should be continued, improved, and intensified. *Chapter 4.*

10. *That there be purposeful regulation of fisheries, now declining in yield because of overexploitation, and effective control of the catch of other stocks that will be threatened in the future.* This involves knotty problems of internal jurisdiction and international negotiation, but they must be overcome. In this case the Department of the Interior, with the collaboration of the State Department and other organizations, has done what it could. But again the effort needs to be increased, improved, and extended. *Chapter 5.*

11. *That fishing efforts toward currently underexploited stocks, both in the sea and in fresh waters, be expanded.* In this sense "fishing" refers not merely to fish, but to the capture of all kinds of edible aquatic organisms, plants as well as animals. Again, the Department of the Interior is already involved and further initiative should come from that department. *Chapter 5.*

12. *That the use of aquatic "farming" operations, not only in fresh waters, but also in marine and brackish-water bays and estuaries, be improved and extended.* Particular attention should be given to operations that do not compete seriously with use of other resources. Examples are ponds sited in swamps or on tide-flats, and shellfish culture either on the sea bottom or from rafts. Responsibility for this effort could rest equally with the Department of the Interior directly and with the National Science Foundation through its authority under the Sea Grant Program. *Chapter 5.*

Policy with Regard to Nonenergy Mineral Resources

13. *That the re-use and better use of materials that can be recycled be encouraged, and that this be required for mineral commodities known to be in short supply.* Incentives should be devised to encourage the optimum use of met-

als and other materials, as well as proper disposal of spent substances. Research on problems and methods of re-using or otherwise extending the lifetimes of all kinds of materials, as well as the recovery of wasted or deleterious by-products, should be supported, both for conservation and to reduce problems of pollution and waste disposal. The automobile is a prime target for improvement. The copper content of the average car should be reduced from about 1.4 percent to 0.4 percent or less of the total carcass and problems of metal recovery simplified. The metals involved could then be used repeatedly, with greatly reduced waste and with elimination of unsightly modes of disposal. New methods of combining metals in clad structures, for instance, make it possible to utilize the desired properties of special metals (such as silver and copper) with great economy, better structural properties, and reduction to levels that eliminate the adverse effects of mixing. Other targets are the wasteful disposal practices that could be improved to salvage more used metal. Military uses, of course, are especially demanding on supplies of relatively rare metals. To the many urgent reasons for seeking peace and for damping the arms race must be added the conservation of unreplaceable resources for future generations. In addition, the Departments of the Interior and Commerce should be authorized and directed to collaborate in developing and instituting a practicable and effective metal conservation program. *Chapters 2, 6.*

14. *That action should be taken to reduce the lag between the recognition of probable mineral-resource shortages and investigations intended to alleviate them.* It takes an average of about five years from the beginning of surface exploration for new deposits to be found on land and another five years of underground exploration and development to bring them into production. Even longer lead times will be needed in developing marine mineral resources. And very long lead times must be allowed for the surveys and research needed to establish an exploratory framework or to underpin long-range forecasts. Specific recommendations on such matters should be a primary function of the Department of the Interior, which should also continue and expand its exploration programs. *Chapters 6, 7.*

15. *That geological exploration of the continental shelves and borderlands be accelerated and intensified.* The continental shelves, slopes, and rises, and the inland seas, are the parts of the seabed that are most likely to contribute useful and abundant mineral commodities to supplement our depleting reserves on land. They should be studied not only for their broad surficial features, but also at depth by drilling, and in areal detail in regions that offer good prospects either of containing mineral resources or of contributing to an understanding of their origin. Contiguous areas ripe for such detailed studies include the Atlantic shelves and the Gulf of Mexico, the continental border-

land of southern California, and the Bering shelf. In emphasizing the continental margins, of course, we merely stress the logical priorities. We do not overlook, but rather consider as severely limited, the possibility of resources from the other 75 or 80 percent of the sea. Programs now in progress on the continental shelves by the Department of the Interior should be continued, enlarged, and wherever possible improved; and Interior's cooperative efforts with university groups should be increased. *Chapter* 7.

16. *That legal problems involved in marine exploration and mining be resolved with as little delay as possible, and international agreements established to facilitate underwater exploration.* Neither national nor international law is really clear as to the limits within which discoveries made may be claimed by private, state, or national interests. Clarification is needed, both to encourage exploration and to avert troublesome disputes over ownership of marine resources beyond the continental shelves. National interests beyond the continental slopes could well be submerged in favor of some workable international jurisdiction such as suggested in the "Maltese Proposition"—with gain for international cooperation and little loss of potential territorial wealth. The Departments of the Interior, Commerce, and State should work together on these problems. *Chapter* 7.

Policy with Regard to Sources of Energy

17. *That the development of high-neutron-economy reactors be accelerated, including an efficient and safe type or types of breeder reactor(s).* The development of nuclear energy is an urgent national and global goal because of the approaching depletion of fossil fuels and the need to conserve them for other purposes. But without greater utilization of uranium-238 and thorium-232 through breeding or other efficient conversion, the economics of nuclear power is such that the supply of uranium-235 from high-grade ores at current prices could become severely restricted within a few decades. The achievement of nuclear fusion, of course, would greatly extend nuclear reserves in the very long term, and fundamental research in this field should be continued. *Chapter 8*.

18. *That the fossil fuels be conserved for uses which cannot be met by other sources.* The fossil fuels (petroleum, natural gas, coal) are needed for petrochemicals, synthetic polymers, and essential liquid fuels, for which suitable substitutes are as yet unknown. They might also play a part in synthetic or bacterial food production (although such a use is also limited). They should not be spent in the generation of electricity, for heating, and for industrial purposes where substitutes can qualify. The Department of the Interior should be authorized and directed to develop and institute a practicable and effective hydrocarbon conservation program. *Chapter 8*.

RESEARCH

Research is clearly an essential component of many of the preceding recommendations, yet there are additional topics in need of intensified research which we believe deserve early attention. The Committee on Resources and Man, therefore, recommends greatly increased research on:

General

19. *The complex of nonmaterial factors that affect man's use of and demand for resources.* Although circumstances required the present Committee to bypass most aspects of such a study, our inquiries so strongly reinforce the need for it that we urge the formation of another group to study the various social, psychological, legal, medical, religious, and political aspects of the problems of resources and man that we have been forced to set aside. What, for instance, are the consequences of man's different conceptual environments—of how he imagines things to be regardless of how they really are? What is the effect of religion and religious differences on the nature of and demand for resources? How can cultural preferences be altered so as to relieve demand on resources and reduce pollution while minimizing social disruption? What are the processes whereby regulation of family size is best achieved? How do resources and economic factors really interact? What are the resource consequences of technological development and of different densities and patterns of human settlement? As with Recommendation 7, the National Science Foundation would do well to consider this an area of major focus for its growing program in the behavioral sciences. The Department of Health, Education, and Welfare, of course, should also be involved.

Sources of Food

20. *Tropical lands and crops.* The tropics are among the most thickly populated regions of the earth, yet they produce insufficient food for their populations. This poor productivity in food resources for humans is in part due to the unusual ecological diversity of large parts of the tropical climatic zone. It is also in part due to geologic and climatic factors which make many tropical soils (lateritic and leached soils) deficient in mineral nutrients and resistant to tilth as compared with those of the middle latitudes. It will require more than good seeds and good management to turn the Amazon Basin into another "breadbasket." Assuming it can be done, it will require enormous quantities of mineral fertilizer and a good share of creative agricultural science. These and interacting sociological and economic factors must be weighed in seeking to develop new food crops that could increase the present productivity of tropical regions without seriously impairing their

ecological stability. This is clearly a job for the Department of Agriculture, with the collaboration of the State Department; but continuation of the good works of the Rockefeller Foundation should be encouraged, and the participation of the National Science Foundation in the long-range aspects of the program through the sponsorship of private institutions is also important. *Chapter 4.*

21. *The productivity of the sea and fresh waters.* How can aquatic productivity useful to man be increased and a larger fraction of food be harvested from the waters without endangering desirable species? The variety and quantity of food products from the sea might be increased (a) by transplantations shown to be feasible as a result of studies of the life cycles and ecological adaptivity of organisms; (b) by more widespread culture of food animals; and (c) by improved methods of capture. More intensive fishing for some species is desirable, whereas for others greater yield must be sought by restricting fishing effort under international agreement. Research alone can produce the information needed to resolve such questions. This recommendation involves a clearly defined mission of the Department of the Interior, but it could also appropriately be furthered by National Science Foundation grants in the underlying supporting disciplines such as aquatic biology and ecology. *Chapter 5.*

22. *Methods of harvesting currently unused but edible aquatic organisms.* Many species of marine organisms can be eaten and occur in quantity but are difficult to catch in large volumes. A practicable method for harvesting the larger species of animal plankton, for instance, would permit us to work closer to the base of the food pyramid and thus to utilize a larger fraction of the total stock. Although this would carry the risk of affecting other fisheries adversely, it might be done in regions where the planktonic animals are not being consumed in quantity by usable animals. The small crustaceans called krill, for example, although abundant in both Arctic and Antarctic seas (and formerly harvested by whales) are not now being utilized. This recommendation involves an established mission of the Department of the Interior, but the National Science Foundation could also play a part through support for this objective under its Sea Grant program. *Chapter 5.*

23. *The processing, marketing, and consumer-acceptance of products such as fish-protein concentrates.* Proteins and fats from the waters could be much more widely and effectively used in human nutrition if organisms not now acceptable for food as harvested could be concentrated in palatable form. In view of their established missions, this recommendation concerns the Departments of the Interior, Commerce, and State. *Chapter 5.*

Mineral Resources

24. *The geology, discovery, and development of ore deposits.* Especially needed are studies of the genesis, localization, and discovery of ore bodies that have no surface manisfestation—"blind" ore bodies. New methods must be employed in seeking such ores, and better methods are needed in evaluting and recovering them. Concepts of metallogenic provinces also need to be clarified and extended; for they might help greatly with the intensified geochemical census urged in Recommendation 2. Equally needed is research on the geology, exploration methods, and evaluation and recovery of marine mineral resources. The U.S. Geological Survey and the U.S. Bureau of Mines should be encouraged to expand and improve their programs dealing with such problems. *Chapters 6,* 7.

25. *The geology of the sea floor beyond and adjacent to the continents.* Although prospects of specific rewards should not be called upon or required to justify exploration of the deep sea floor, *some* new mineral wealth can certainly be expected as a partial consequence. Such bonuses, to be sure, are just as likely to come from a better understanding of the processes involved in the origin of land deposits as from actual discovery of ore deposits at the sea floor. At the very least, sea floor studies will contribute to better concepts of the structure, evolution, and management of the earth. Such research can and should be undertaken by a number of different government, private, and university organizations, and all should be encouraged. The continued healthy growth of the Sea Grant program of the National Science Foundation could serve this end. *Chapter* 7.

ORGANIZATION

Because national and international welfare and harmony ultimately depend on natural resources, and since conditions affecting resources are constantly changing, it is only prudent to monitor these changes in such a way that crises of supply or environmental degradation can be foreseen and ameliorated. As an important move toward such a review and warning system, therefore, we recommend:

26. *That there be established, at an appropriate location within the United States government, a high-level group of broadly qualified resource specialists and ecologists having the following duties—*

(a) to maintain continuing surveillance of both nonrenewable and renewable resources, particularly with regard to the future;
(b) to inform the government and the public concerning impending short-

ages, problems of environmental deterioration, and other prospective developments affecting natural resources;

(c) to recommend to the government well in advance of crises optimum courses of action, not only for the avoidance of resource shortages and environmental catastrophe, but equally for the achievement of maximum social well being and international harmony in the uses of resources.

2/Interactions Between Man and His Resources

John D. Chapman

"Resources are not; they become."
—E. S. Zimmerman, 1951, p. 15

It is the purpose of this chapter to introduce a geographer's view of the relations between resources and man. In such a context one looks upon the elements of the physical world as having significance only in relation to the inhabitants for whom they constitute environment. The particular elements or combinations of elements that are significant vary according to whether human, animal, or plant life is involved; each has its own system and subsystems, separately identifiable but all more or less interlocked. In the human ecosystem, man assigns untility to various elements of his environment and thus confers upon them the role of resources. Resources then are neither wholly of the physical world nor wholly of the world of man but are the result of the interaction between the two. The environmental elements that man calls upon to serve as resources, and the nature and size of the requirements he places upon them, depend on his numbers, his needs and desires, and his values and skills.

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RESOURCE REQUIREMENTS

Man's resource requirements depend, among other things, on the sizes and distribution of populations. On the global scale he is faced with a relentless population growth and with increasing concentration into particular regions. Within such regions, there is further concentration into urban, metropolitan, and megalopolitan nodes. While each additional human being requires an increment of basic necessities such as food, water, shelter, and space, he also requires more. How much more, and of what, depends upon his individual tastes and desires as well as his ability to satisfy them. Mankind collectively is in the midst of a "revolution of rising expectations," involving a universal commitment to the concept of economic growth as "an irreversible and irrepressible need" (Jaguaribe, 1966).

The gap between economies characterized by massive consumption and modest population and those characterized by low consumption and massive population is seen by many as a major contributor to world instability. Large-scale efforts have been made and are being made to narrow this gap and to diffuse higher per capita consumption to an ever greater proportion of the world's population. Some realists observe that, although the minimum levels are indeed being raised, the gap is widening, not closing (Myrdal, 1965). Others speculate about world requirements for metals, fuels, and food if the per capita consumptions of the North Atlantic economies are to be approached elsewhere. Relating such requirements to their expectations for available resources, they see, in the short run, the prospect of an attractive market situation; in the long run, the specter of scarcity and exhaustion.

In economies with already high per capita economic development, further increments of growth contain smaller requirements for material input (Barnett and Morse, 1963). In such economies, reduction in the rate of growth of the required quantity of new material input (i.e., resources) is accompanied by a growing concern for the "quality of the environment" (Jarrett, 1966). There is the implication that as a society reaches some threshold of economic development, with its attendant scientific and technological capabilities, it can afford to concern itself less with materials and quantity and more with the quality of life. Whether this implication is true or not, and however we define our terms, attaching utility to the quality of environment has the effect of perceiving as resources some aspects of the environment not previously considered to be resources—the appearance of the landscape, wilderness, animal life, plant associations, and the like. A range of new problems thus emerges (Krutilla, 1967).

More serious are recently formulated questions that squarely challenge the need for and desirability of continued expansion of per capita consumption (Boulding, 1966). Does not this very expansion create indirect costs (e.g., waste disposal, health hazards) that outweigh the benefits? Is it possible that

American standards of consumption are excessive and that to accept them as world targets is a tragic mistake? Can improvements in the quality of the environment and of life be most satisfactorily achieved at a lower level of material consumption than is associated with the "average" American today?

Questioning voices, however, are rarely heard above the broad swell of belief in what is considered to be the inherent necessity for economic growth and increased per capita consumption. When coupled with an increasing population, such rising expectations seem bound to increase resource requirements at exponential rates.

RESOURCE AVAILABILITY

The availability of resources at any time is the result of the interactions among the nature and size of man's requirements, the physical occurrence of the resource, and the means of producing it. Estimates of the future availability of resources, therefore, require the assessment of: (a) the particular combination of economic and technological conditions that determines *present* production, (b) the level of production that *would* take place under different economic conditions, (c) the level of production that *could* take place under different technological conditions, and (d) the nature and quantity of the total physical stock of both "renewable" and "nonrenewable" resources. Because the relations between these physical and human variables are complex and vary with time and place, views concerning future supply need to be carefully expressed and set in a context such as the threefold hierarchy of total stock, resource, and producible reserve. These concepts are summarized below from the work of Lovejoy and Homan (1965), substituting the term *total stock* for their use of *resource base*.

Total stock is the sum of all components of the environment that would be resources if they could be extracted from it. Assessment of the total stock is largely the concern of earth and life scientists, and the state of knowledge concerning it depends on the adequacy of prevailing theory, the state of exploration and survey technology, and the extent of its application. Applied to what are conventionally referred to as nonrenewable resources, the total stock is finite and thus eventually exhaustible. Applied to renewable resources, the total stock consists of highly complex systems in a state of dynamic, delicately balanced, and only partially understood, equilibrium.

Resources comprise that proportion of the total stock that man can make available under technological and economic conditions different from those that prevail. The state of technology assumed will set the limits within which different economic and social variables can determine what proportion of the total stock can become available. Assessment of a resource involves not only physical and biological scientists but applied and social scientists as well.

They must make judgments about the directions and rate of change of technological developments (e.g., gradual increase of efficiency of extraction of a mineral deposit or yield of a crop as against dramatic, order-of-magnitude, breakthrough changes); about the impact of changed economic conditions and new alignments in international relations; and about public attitudes on such varied matters as birth and population control, transportation preferences, and clean air. In essence the question is one of judging man's potential for creating resources out of the total stock; of selecting the chief agent of change from among technological, economic, or other societal forces; and of determining the relevant time and space dimensions. Resource estimates are speculative in proportion to the extent to which they go beyond prevailing conditions and the amount by which they extend the time and space over which they apply.

Reserve refers to that proportion of a resource that is known with reasonable certainty to be available under prevailing technological, economic, and other societal conditions. This term embraces current extraction rates, yield, management practices, legal frameworks, and social attitudes. It is therefore the least speculative, shortest term, most place-specific, and smallest of the three types of estimates.

These three concepts provide a framework into which each of the many estimates of resource availability may be fitted and thus be seen in perspective. By providing a rationale that can accommodate what often appears to be starkly conflicting professional opinions, these concepts reduce the ground for misunderstanding, overoptimism, or undue pessimism. Furthermore, they incorporate the notion of resources moving from one threshold of availability to another in response to changing values of variables under human control, allow estimates to be made in physical or economic terms, and yet permit retention of the essentially "physical world" character of the materials involved.

TIME, SPACE, AND TECHNOLOGY

Among the many factors that affect the relation between the requirements for and the availability of resources, those of time, space, and technology are selected for particular mention here, because, despite their acknowledged importance, they often do not receive explicit treatment.

Time

In the discussions concerning resources and man, what time dimensions are appropriate and in what terms should they be expressed? Conservationists point to the need for thinking in terms of generations to come. Biologists are

concerned with the contrast between the long time required for ecological processes to establish a dynamic equilibrium and the short time it takes man to introduce major instabilities. Statements, however, are rarely time-specific.

An exception, in an ecological context, is found in Chapter 8, in which M. King Hubbert sets out a time scale in thousands of years on either side of the present, in order to illustrate the recency of prevailing per capita energy consumption and its potentially short life unless nuclear energy becomes available in large quantities. Landsberg, Fischman, and Fisher (1963) conducted a survey of U.S. resources that specifically dealt with the interval ending in the year 2000. Barnett and Morse (1963) have used a set of schematic curves to illustrate, in economic terms, their concept of the influence, over an increment of time, of technology on resource availability.

The appropriate time scale within which to deal with questions concerning resources and man depends on whether the questions being raised have operational, planning, or policy-making implications and on what resources are involved. Some would say that one should look ahead only as far as the impact of prevailing technology and other societal arts can be discerned. The extreme expression of this view is that, because the rate of technological change is so rapid, projections concerning resources, which so intimately involve technology, are relatively meaningless. Others claim that more distant vistas must be scanned in order to demonstrate that unless change is initiated in directions suggested by such reviews, there will be insufficient time to avoid drastic consequences.

In what terms should the time dimension be expressed? In absolute numbers of years, such as decades or centuries, chosen on the basis of some bench mark (e.g., midcentury, centennial, year 2000); in relative terms, such as human generations or time to harvestable maturity; or in some more complex derived terms, such as the period required to double the population or to reach the "take-off" period in a developing economy.

Whatever the answers to the above questions, the important thing is to ensure that no question is raised and no answer offered without being accompanied by an explicit statement of the time period to which it refers and by an evaluation of the factors that have been considered. The more restricted the time scale adopted, the less intractable the resource problems can be shown to appear; and vice versa. With no time scale the way is open to diametrically opposed interpretations.

Space

The spatial context refers particularly to such matters as spatial scale, location, distribution, and interaction. These are dimensions of resource problems that, although frequently mentioned, are rarely dealt with explicitly.

As communications have improved it has become common to speak of one

world. In the past, interaction across great distance was often impossible or severely limited, because of either the lack of or the high cost of transportation facilities. Today, with the advent of bulk carriers, pipelines, highways, and other transportation systems, these restraints have been, or can be, greatly reduced. As a result we see massive long-distance distribution of previously "shut-in" resources to consuming areas, which can now look farther and farther afield for supply and can consider imports as a realistic alternative to scarcity or reliance on domestic resources alone. Furthermore, the space that may be affected by some developing technologies (e.g., offshore drilling, undersea mining, weather modification, nuclear engineering) is much larger than that affected by current practices. All these developments lend support to the notion of a shrinking world in which various factors affecting resources interact more and more complexly.

Despite these strong tendencies, the fact is that the physical environment, the cultural values, the political systems, and the levels of economic development continue to exhibit marked areal differentiation. Since these are the variables that determine the relations between resources and man, and since they differ strikingly from place to place, it becomes difficult to say anything useful about this man-resource relationship on the global scale.

In fact, there is not just one world of resource requirements and availabilities but many. The access of a particular area of consumption or potential consumption to one of supply (and vice versa) is not necessarily assured. Although reduced, physical problems of transportation and cost still exist, as do additional institutional and cultural barriers to spatial interaction, such as political alignments, trade policies, and their manifestations in tariffs. As a result, even when a strong complementarity exists between a "world of surplus" and a "world of want," they remain two world economies, not one. Between them very real barriers may prevent spatial interchange.

What, then, is an appropriate areal framework within which to deal with resources? In general, it is the size of the area over which the variables determining resource requirements and availabilities have been or can be made to have some considerable degree of homogeneity. An obvious example is the nation state. Within it the variables can be brought into focus and, for short- and medium-range intervals of time, statements concerning resources can be made with a high degree of confidence. Thus, for Canada one can specify a number of metals, fossil fuels, and renewable resources, whose availability will continue to exceed domestic requirements until the year 2000. In this statement Canada is the unit of reference—nothing larger, nothing smaller—and the dimensions of this unit determine which factors are internal and which are external.

In general, it might be said that the more restricted the space the more severe the resource problems become, the more rapidly they develop, and the greater is the chance that effects of resource operations will extend beyond

the area in which they are initiated. The corollary to this, of course, is that the greater the area involved the greater the variety of potential resources and opportunities for spatial substitution and dispersion, with attendant decrease of problems and a longer lead time before they emerge. The ecology of resources thus reflects the principle stressed in Chapter 1 – the more diverse systems are the more stable ones.

An important element of the spatial context is the degree of concentration or dispersion. Many problems of resources and environment arise as a result of areal concentration of consumers (for example, spillover effects of wastes produced in urban areas and resulting pollution of water, land, and air). There is not much indication, however, that the pattern of distribution of population will change drastically in the near future on the world or national scale. Rather it appears likely that there will be an increased concentration of population as a result of the coalescence of present nodes. If this occurs, then the resource implications of spatial concentration of population should receive as much attention as those of a nonspatially explicit increase in total numbers. Among other things, we must ask how massive intercontinental migration can be restrained as the pressure of population on resources rises locally. And how shall we resolve the agonizing confrontation between rising ethical standards in the developed world and the needs of the rapidly increasing underprivileged and undernourished for space as well as food?

What are the resource implications of concentration versus dispersion of population? Is there convincing evidence that the forces bringing about concentration will necessarily continue to outweigh the forces causing dispersion? From a resource point of view, should public policy seek ways of accommodating to the seemingly ever-increasing concentration, or should it seek to bring about dispersion? Does society prefer increasing technological complexity, population control, social revolution, or some combination of these things? The spatial scale at which questions such as these are posed and the assumptions made about spatial distribution and interaction will have a significant influence both on the nature of the answers and on the range in space to which they can be extended.

Technology

One of the most fundamental societal factors involved in the interaction between man and nature is the technology that man has at his disposal for discovering, producing, processing, and using the materials of his environment. The range of technology available changes rapidly with time as the total stock of skills and understanding grows, as a result of both many small incremental gains and larger breakthrough advances. This continuous growth and changing capability of technology contributes greatly to the dynamic state of resource issues.

The impact of technological advance upon resources is usually interpreted positively, optimistically, and enthusiastically, for it provides the means of "creating" resources out of environmental material, of substitution, of increased extraction rates, and of greater efficiency of use. On the other hand, the enormous requirements of some technologies in themselves contribute greatly to the depletion of resources and to the production of waste in unprecedented quantities. Furthermore, technology provides the means by which man may ever more effectively challenge nature (White, 1967) and thus be increasingly capable of unbalancing the systems of which it is composed.

In recognizing technology as one of the most powerful forces impinging on the resource scene, one is led to ponder whether, and in what directions, its development is influenced by interactions between resources and man. New technology arises from research and development programs that are themselves started and directed by social, political (including military), and, most frequently, market forces. But there are questions to which the market does not yet know how to react (Krutilla, 1967) and other questions concerning relationships that are expected to exist sufficiently far into the future so that they produce no signals in the marketplace of today. Where technology is the limiting factor, the question is whether the desired technological development will arise. Where scarcity of particular resources may become limiting, the question is whether the market will react far enough ahead to provide time for substitutes to be sought or technological solutions to be devised. (For discussion of such matters see U.S. Department of Commerce, 1967; Nelson, Peck, and Kalechek, 1967.)

The ability to invent and the receptivity to innovation and dispersion of new techniques vary with the degree of development of a society with respect to a range of cultural characteristics, of which education is often seen as the most important. As a consequence, pronounced geographical differences need to be taken into account when evaluating the role of technology in resource development and use. An international corporation may be able to disperse technological change to all its plants regardless of their location, but the dispersal of new varieties of crops to millions of independent users, or the introduction of such users to the use of artificial fertilizer, may face severe spatial limitations. It must be stressed again that in practice there is not one technological world but many, and that to extrapolate from experience in one area to expectations in another is hazardous.

FRAMES OF REFERENCE

Many formulations of the relation between man and resources have evolved over the years. Each of these tends to emphasize a particular factor or group

of factors as determinant, and each has been, or is, sufficiently plausible to receive wide acceptance.

The Malthusian Doctrine

Malthus (1798, p. 13–14) wrote that "the power of population is indefinitely greater than the power in the earth to produce subsistence for man. . . . Population, when unchecked, increases in a geometrical ratio. Subsistence increases only in an arithmetical ratio."

This initial statement of the Malthusian doctrine, or more sophisticated versions, lies at the root of most of society's anxieties about the relations between man and resources. Specific predictions based on such relations, however, must examine the relevance of the underlying assumptions to a particular space and span of time.

Conservation

The meaning of the term *conservation* varies from person to person and time to time, although it is generally associated with resource scarcity and has its roots in the Malthusian formulation (Barnett, 1959; Krutilla, 1967). The conservation idea, however, is often associated with political and emotional overtones. Over the last half century it has been associated with a number of identifiable viewpoints (Herfindahl, 1961). The first of these was probably the concern to define the "limits" of resources by means of inventories and surveys. Second, in order to avoid the problem of approaching the limits of resource availability, the notion of deferring production developed and became the interpretation of conservation generally adopted by economists. A third viewpoint, recognizing that use is unavoidable, emphasizes the need for constant efforts to reduce waste and encourages multipurpose use whenever feasible. A fourth, closely associated with the conservation tradition, calls for the preservation of nature from the ravages of development.

The Ecological Approach

A more recent fo..nulation of the man-resource relationship, with some antecedents in the conservation idea but owing its full development more to biologists than to laymen, is the ecological approach. This approach sees the natural world as a series of interrelated systems in a state of dynamic equilibrium into which man intrudes as an unbalancing factor. The study of these complex, interrelated systems by proponents of this approach has led to support for multiple-path, multiple-choice, and systems-analysis methodology in dealing with resource problems rather than "linear chain-reaction determinism" (Weiss, 1962).

The Technological Fix

During the last decade the Malthusian doctrine and other positions of conservationists have come under attack by economists. The doctrine of scarcity (in economic terms) has been discounted, and at least the part of the conservationist's position that supported the deferment of use has been challenged. The key process supporting such challenge is technological change, particular emphasis being placed on such developments as will permit far-ranging chemical synthesis and offer the prospect of more massive and cheaper supplies of energy than man has ever had at his disposal before. The essence of this view is expressed by Barnett and Morse (1963, p. 10) as follows: "Few components of the earth's crust, including farm land, are so specific as to defy economic replacement, or so resistant to technological advance as to be incapable of eventually yielding extractive products at constant or declining cost."

The position taken is that given mobilization of enough highly trained personnel, money, and equipment, solutions to problems of foreseeable resource scarcities will become available. Some proponents of this view claim that to bring about the necessary technological development is, in the long run, easier than attempting to change social attitudes toward resources and environment (Weinberg, 1966).

The Quality of Environment

In many respects the quest for environmental quality, and the measurement of other goals in relation to this, is closely allied with the ecological approach; but it draws increasingly wide support from physical and social scientists, as well as from the public and government (Jarrett, 1966). Clean air, clean water, beautiful landscapes, and the like are said to become the goals of society when the benefits of technology release it from an overriding concern with material resources.

CONCLUSIONS

Each of the formulations identified above has its proponents in high places and its following in the citizenry at large. Adherence to one or another of them is basically determined by which combination of variables is given the greatest weight, the terms used (e.g., physical, economic, qualitative), and the temporal-spatial context assumed. The differing assumptions from which they depart may lead to such contrasting statements as:

> The notion of an absolute limit to natural resource availability is untenable when the definition of resources changes drastically and unpredictably over time. (Barnett and Morse, 1963, p. 7.)

and

> That such rates of growth are essentially ephemeral, and cannot be continued into the future indefinitely, can be seen by noting that the earth on which we live is finite in magnitude; whereas no physical quantity, whether the human population, the rate of energy consumption, or the rate of production of a material resource such as a metal, can continue at a fixed exponential rate without soon exceeding all physical bounds. (Hubbert, 1962, p. 125.)

Which of the many variables are the determinants, which of the several perspectives the most germane? There is no one answer for all time and all places. Reality requires that account be taken of variations both in time and space together, and that is where the greatest difficulties and contradictions arise.

The commitment of highly respected individuals and groups to particular perspectives, and the resulting variety of positions, is both confusing and troublesome. If policy makers, managers, and the public at large become committed too far to one outlook, the danger arises that some insights of the others will be lost or that debate will center on the polemics of the bias in vogue. Preferable is a continuing balanced appraisal of the complex and dynamic interaction between man and resources, set explicitly in the context of the range of perspectives available and varying with the times and places involved. Perhaps the most helpful thing that could happen would be for students of the problem to agree on a few models in time, space, population density, and level of living that would become frames of reference for the unambiguous evaluation of resource sufficiency.

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8/Energy Resources

M. King Hubbert

"The optimist proclaims that we live in the best of all possible worlds; and the pessimist fears this is true."
—James Branch Cabell, 1926, p. 129

Into and out of the earth's surface environment there occurs a continuous flux of energy, in consequence of which the material constituents of the earth's surface undergo continuous or intermittent circulation. By far the largest source of this energy flux is solar radiation, a small fraction of which is captured by the leaves of plants and stored as chemical energy. This chemically stored solar energy becomes the essential biological energy source for the entire animal kingdom. In particular, it supplies the energy required as food for the human population at an average rate of about 2,000 kilocalories per capita per day, or at a per-capita consumption rate of about 100 thermal watts.

During geologic history, a minute fraction of the organic matter of former plants and animals became buried in sedimentary sands, muds, and limes, under conditions of incomplete oxidation. This has become the source of our present supply of fossil fuels—coal, petroleum, and natural gas.

During the last hundred thousand years or so, the human species has slowly learned to manipulate the energy supply of its biologic and inorganic environment in such a manner as to produce a continuous increase in its total energy supply, and a resulting increase in its population. However,

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until recent centuries the increase in the rate of total energy consumption was very much less than the increase in the rate of population growth. Consequently, the population has tended to remain in balance with the increase in energy supply, while the biologic and inorganic energy consumed per capita remained at a low, nearly constant level—only slightly more than that of the food supply.

Release from this constraint was not possible until an energy supply capable of exploitation faster than the human population could grow should become available. Such an energy supply is that represented by the fossil fuels. Continuous mining of coal began about eight centuries ago and production of petroleum just over one century ago. From small beginnings, the use of energy from these sources has grown until, during most of the last century, world consumption of energy from the fossil fuels has increased at about 4 percent per year. The world's human population has also responded to this stimulus and is now growing at a rate of just under 2 percent per year. Hence, at present, the world's average nonnutrient energy consumption per capita is increasing at about 2 percent per year.

Since the earth's deposits of fossil fuels are finite in amount and nonrenewable during time periods of less than millions of years, it follows that energy from this source can be obtained for only a limited period of time. In the present study, it is estimated that the earth's coal supplies are sufficient to serve as a major source of industrial energy for two or three centuries. The corresponding period for petroleum, both because of its smaller initial supply and because of its more rapid rate of consumption, is only about 70–80 years.

In particular, it is estimated that the United States (exclusive of Alaska) will reach its culmination in crude-oil production near the end of the 1960-decade and its culmination in the production of natural gas about a decade later. The date at which world production of petroleum will reach its maximum is estimated to be about the year 2000, or about 30 years hence.

In view of the fact that 60 percent of the world's present production of energy for industrial purposes, and 67 percent of the United States', is obtained from petroleum and natural gas, the imminent culmination and decline in the annual supplies of these fuels poses problems of immediate concern. In the United States, in particular, there is a need for immediate formulation of policies concerned with making up the deficit in the supply of liquid and gaseous fuels soon to result from the decline in the production rate of oil and natural gas.

Looking farther into the future, the energy needs of the United States and the world could be met for another century or two by coal alone. After that, dependence upon other sources of energy would become unavoidable. Of these, large-scale power production directly from solar energy appears technologically unpromising. The world's potential supply of water power is comparable in magnitude to the present rate of energy consumption from

the fossil fuels. However, most of this occurs in the industrially undeveloped areas of Africa, South America, and southeast Asia, and could only be utilized by a parallel industrialization of these areas. In addition, although water power is capable of continuing for periods of geologic time, a practical limit in the case of large dams and reservoirs is set by the period of a few centuries required for the reservoirs to fill with sediments.

Geothermal and tidal energy is now being exploited in a few suitable sites around the world, but the ultimate amount of power from these sources does not promise to be larger than a small fraction of the world's present power requirements.

This leaves us with nuclear energy as the only remaining energy source of sufficient magnitude and practicability of exploitation to meet the world's future energy needs at either present or increased rates of consumption. Of the possible sources of nuclear energy, that from fusion has not yet been achieved and may never be. Power from the fission of uranium-235 is an accomplished fact, and reactors in the 500 to 1,000 megawatt-capacity range, fueled principally by this isotope, are rapidly being constructed. However, the supply of uranium-235 is such that serious shortages in the United States are already anticipated within the next two decades.

In the light of present technology, we are left then with the development of full-breeding nuclear reactors capable of consuming all of natural uranium or of thorium as our only adequate source of long-range industrial power. In view of the impending shortage of uranium-235, which is essential as an initial fuel for breeder reactors, it is urgent that the present generation of light-water reactors using uranium-235 be replaced by full breeders at as early a date as possible. Once this has been done, power production from low-concentration deposits of uranium and thorium becomes economically practicable. The amount of energy represented by these sources is many times larger than that of the fossil fuels.

With the nation's and the world's principal industrial energy requirements supplied by nuclear energy, it would be desirable to conserve the remaining fossil-fuel resources for chemical purposes. More important, with an adequate energy supply, and with a stabilization of the world's human population at some near optimum magnitude, it should be possible to extend the high energy-per-capita standard of living now characteristic of its more industralized areas to all of the world's peoples.

ENERGY IN HUMAN AFFAIRS

When *Homo sapiens* evolved from his immediate hominid ancestors a hundred thousand years or so ago, he existed in some sort of ecological adjustment with the rest of the ecological complex, and competed with other members of that complex for a share of the contemporary flux of solar

energy essential for his existence. At its earliest stage, the sole capacity of the human species for the utilization of energy must have been limited to the food which it ate—then, as now, about 2,000 kilocalories, or 8 million thermal joules, per capita per day.

Between this earliest stage and the dawn of recorded history, this species distinguished itself from all others in its inventiveness of means for the conquest of a larger and larger fraction of the available energy. The invention of clothing, the use of weapons, the control of fire, the domestication of animals and plants, all had this in common: each increased the fraction of solar energy available for use by the human species, thereby upsetting the ecologic balance in favor of an increased population of the human species, forcing adjustments of all other populations of the complex of which the human species was a member.

From that early beginning until the present this progression has continued at an accelerating rate. It has involved the employment of beasts of burden, the smelting of metals, using first wood and later coal as fuel, and the development of power from water and wind. However, throughout this period until within the last few centuries the rate at which these changes were accomplished was slow enough that the growth of population was more than able to keep pace. The rate of consumption of energy per capita, therefore, increased but slightly.

Emancipation from this dependence on contemporary solar energy was not possible until some other and hitherto unknown source of energy should become available. This had its beginning about the twelfth or thirteenth century when the inhabitants of the northeast coast of England discovered that certain black rocks found along the shore, and thereafter known as "sea coales," would burn. From this discovery, there followed in almost inevitable succession, the mining of coal and its use for domestic heating and for the smelting of metals, the development of the steam engine, the locomotive, steamships, and steam-electric power.

This progression was further augmented when, a little more than a century ago, a second large source of fossil energy from petroleum and natural gas was tapped, leading to the internal combustion engine, the automobile, the aeroplane, and diesel-electric power.

A third source of energy, that from the atomic nucleus, was first brought under control as recently as 1942, but already it is rapidly becoming the world's largest source of power.

INDUSTRIAL ENERGY

Our principal concern in the present chapter is with the large quantities of energy required for industrial purposes, as contrasted with biological requirements. This had its principal development as the result of the ex-

ploitation of the fossil fuels. Although this began some eight centuries ago, the magnitudes reached before the nineteenth century were almost negligible compared with those reached subsequently. Our present analysis, accordingly, need not extend earlier than about the year 1800. Furthermore, earlier than 1860, statistical data become increasingly unreliable and difficult to assemble.

Since 1800, the principal sources of the world's industrial energy have been the fossil fuels and water power. The rise in the world's annual production of coal and lignite since 1860 is shown graphically in Figure 8.1, that of the world's crude-oil production since 1880 in Figure 8.2, and the annual production of energy from coal and crude oil in Figure 8.3. From Figure 8.3, it is seen that the energy from oil, as compared with that from coal, was almost negligible until after 1900. Since then, the contribution of oil to the total energy supply has steadily increased until now it is approximately equal to that of coal, and increasing more rapidly. Not included in Figure 8.3 is the energy from natural gas and natural-gas liquids. Were this added to that of crude oil, the energy represented by the petroleum group of fuels would by now (1968) be about 60 percent of the total from coal, petroleum, and water power. Water power alone contributes only about 2 percent.

The corresponding growth in the rates of production of coal, of crude oil,

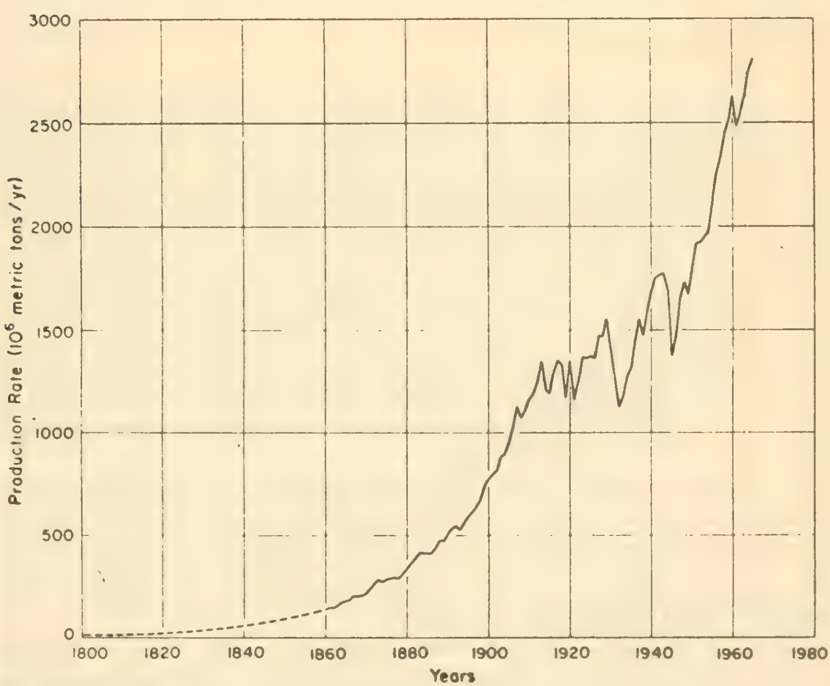

FIGURE 8.1
World production of coal and lignite.

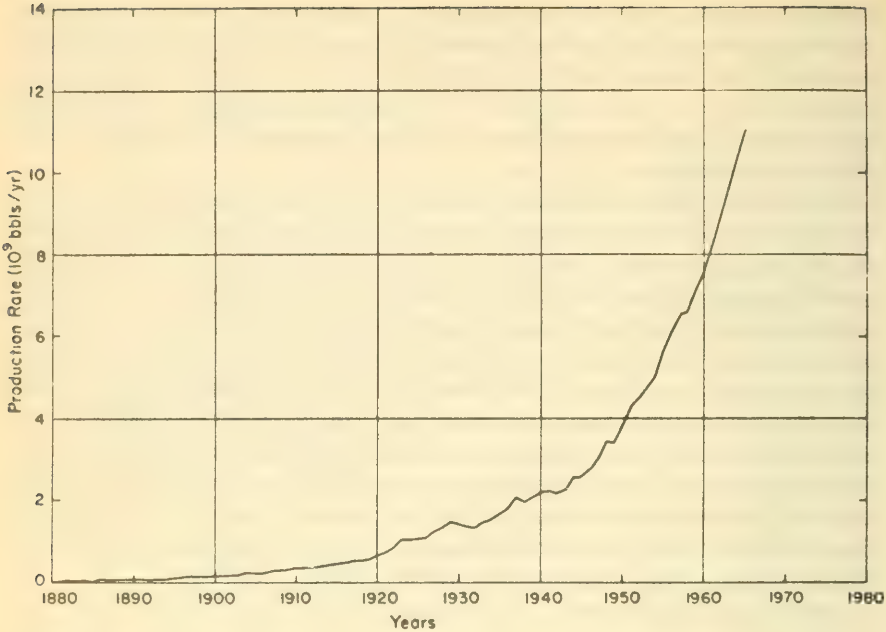

FIGURE 8.2
World production of crude oil.

and of natural gas in the United States are shown in Figures 8.4, 8.5, and 8.6, respectively. The growth in annual production of energy in the United States from coal, oil, natural gas, and water and nuclear power is shown in Figure 8.7. In the United States, as in the case of the world, since 1900 there has been a progressive increase in the fraction of the total industrial energy contributed by oil and natural gas. This fraction increased from 7.9 percent in 1900 to 67.9 percent by 1965. The contribution of coal, during the same period, decreased from 89.0 percent to 27.9. Water power, although continually increasing in magnitude, maintained a nearly constant percentage of the total energy produced. It increased only from 3.2 percent in 1900 to 4.1 percent in 1965. Nuclear power, by 1965, represented only 0.1 percent of the total.

These several growth curves have many properties in common. When replotted on semilogarithmic paper, each plots as a straight line for a period of a half-century or longer, indicating a constant exponential rate of growth. Following this period of constant growth rate, the rate of production falls steadily below its initial linear projection.

In the case of world coal production shown in Figure 8.1, the production rate falls into three distinct phases. During the first, extending from before 1860 to 1913 (the beginning of World War I), the production rate increased

exponentially at an average rate of 4.4 percent per year, with the annual production doubling every 16 years. During the second period, including the two world wars and the intervening depression, the growth rate slowed to 0.75 percent per year with a doubling period of 93 years. Finally, during the third period from World War II to the present, a growth rate of 3.6 percent with a doubling period of 20 years has been resumed.

The world production of crude oil, except for a slight retardation during the depression of the 1930's and during World War II, has increased from 1890 to the present at a nearly constant exponential rate of 6.9 percent per year with a doubling period of 10 years. The second phase of retarded growth rate has not yet been reached.

From 1850 to 1907, the curve of the U.S. production of coal and lignite followed a constant exponential growth rate of 6.6 percent per year with a doubling period of 10.5 years. Before 1850, the growth rate was somewhat higher, but the production rate was so small that this period is not significant. From about 1910 to the present, production has oscillated about an average rate of about 550 million short tons per year.

U.S. crude-oil production, from 1875 to 1929, increased at a rate of 8.3

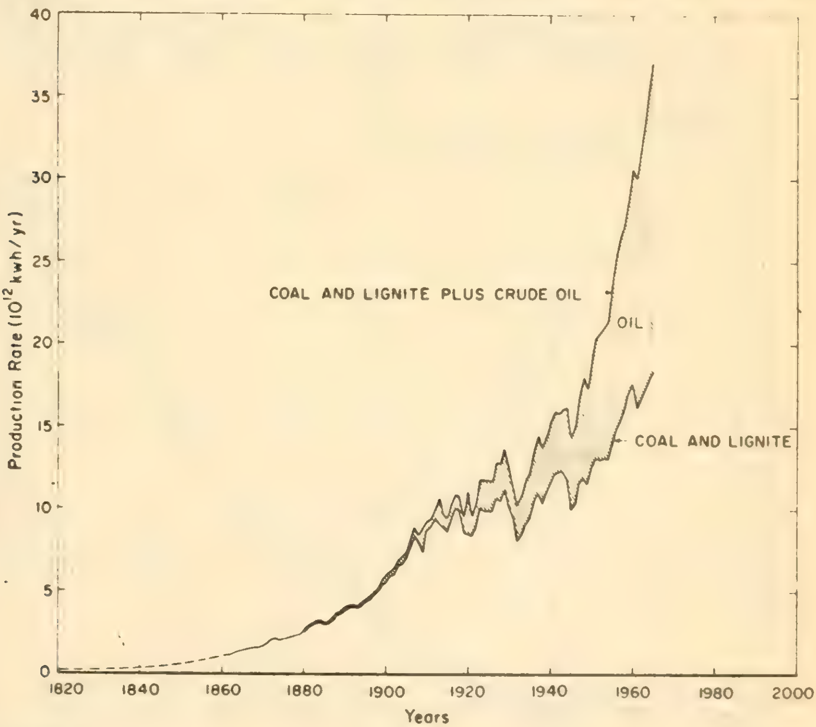

FIGURE 8.3
World production of thermal energy from coal and lignite plus crude oil.

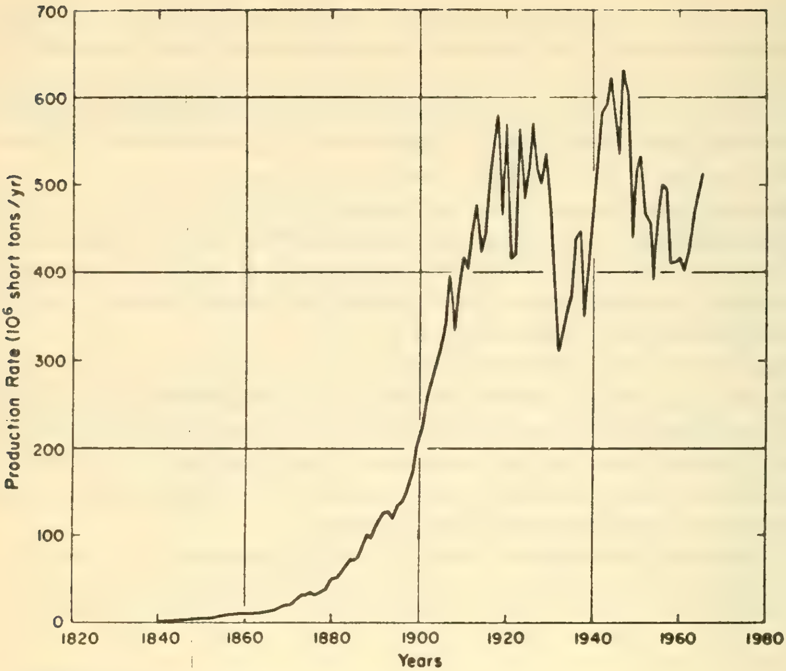

FIGURE 8.4
United States production of coal and lignite.

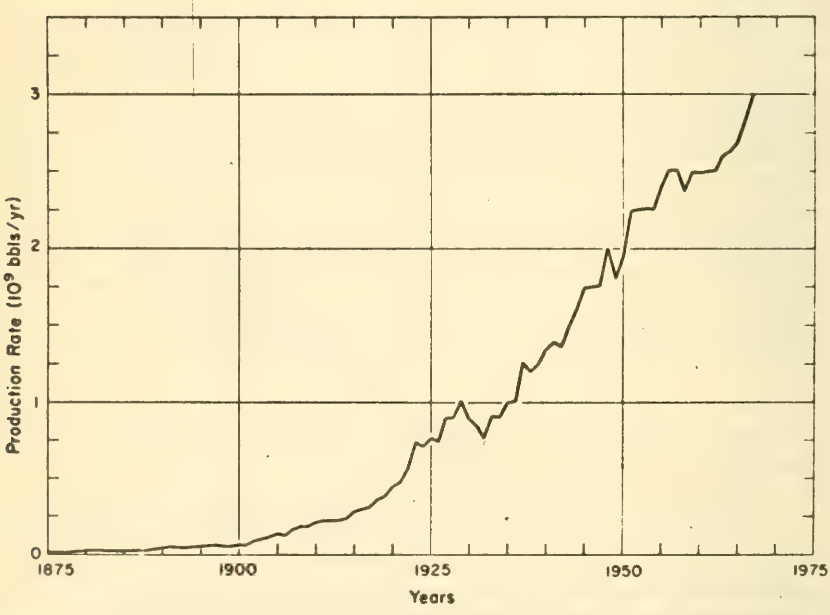

FIGURE 8.5
Production of crude oil in the United States, exclusive of Alaska.

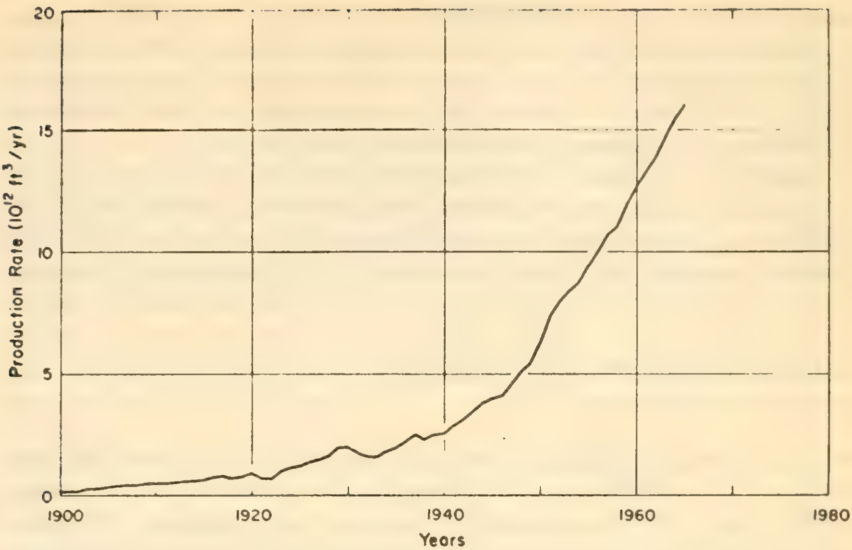

FIGURE 8.6
Production of marketed natural gas in the United States, exclusive of Alaska.

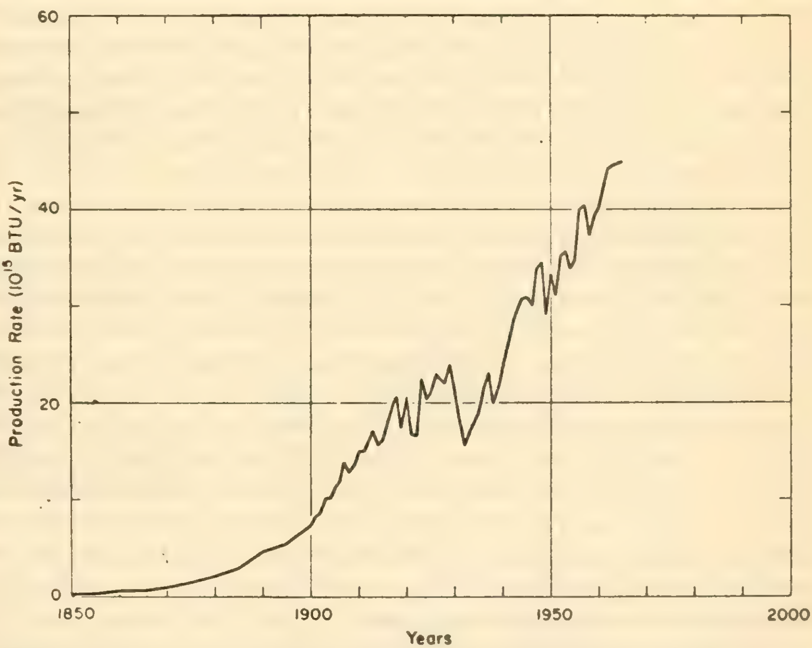

FIGURE 8.7
Production of thermal energy from coal, oil, gas, and water power in the United States, exclusive of Alaska.

percent per year with a doubling period of 8.4 years. Since 1929, the curve has gradually leveled off as the rate of production approaches its maximum. In parallel with crude oil, the U.S. production of marketed natural gas, from 1905 to the present, has increased at an almost constant exponential rate of 6.6 percent per year with a doubling period of 10.5 years.

Finally, U.S. production of total energy from coal, oil, natural gas, and water power, divides into two distinct growth periods. From before 1850 to 1907, energy was produced at a growth rate of 6.9 percent per year with a doubling period of 10.0 years. Then, from 1907 to the present, the growth rate dropped to 1.77 percent per year with a doubling period of 39 years.

Future Outlook for the Production of the Fossil Fuels

When consideration is given to the factual data pertaining to both the world and the U.S. rates of production of coal and oil, as shown in the preceding figures, two results of outstanding significance become obvious. The first of these is the extreme brevity of the time during which most of these developments have occurred. For example, although coal has been mined for about 800 years, one-half of the coal produced during that period has been mined during the last 31 years. Half of the world's cumulative production of petroleum has occurred during the 12-year period since 1956. Similarly, for the United States, half of the cumulative coal production has occurred during the 38-year period since 1930, and half of the oil production during the 16-year period since 1952. In brief, most of the world's consumption of energy from the fossil fuels during its entire history has occurred during the last 25 years.

The second obvious conclusion from these data is that the steady rates of growth sustained during a period of several decades in each instance cannot be maintained for much longer periods of time. The reason for this is that a steady exponential rate of growth implies a doubling of the production rate at equal intervals of time. This also involves the doubling of the cumulative production during the same time interval. Take, for example, the production of crude oil in the United States prior to 1930. During this period, the cumulative production was doubling every 8.4 years, and by 1930 it had reached 12.3 billion barrels. Were this rate of growth to be maintained for another century, about 12 more doublings would occur and the cumulative production would reach 48,000 billion barrels, which is about 74 times the highest estimates on record of the possible amount of oil that may ever be produced in the United States. Similar results are obtained for each of the other fuels shown in the preceding figures.

From such considerations we are led to the conclusion that the time span for the exhaustion of the bulk of the various fossil fuels, under modern

industrial rates of consumption, is measurable in centuries, whereas the time required for the formation of these fuels by geological processes was about 600 million years. Hence, the rates of formation of these deposits are negligible as compared with their rates of consumption. Consequently, during the period of human exploitation, the resources of the fossil fuels may be considered to consist of fixed initial supplies which are continually diminished by human consumption. The quantity remaining in the ground at any given time must be equal to the difference between this initial supply and the cumulative production up to that time. Therefore, the complete history of the production of any fossil fuel must display the following characteristics. The curve of the rate of production, plotted against time on an arithmetic scale, must begin at zero, rise until it passes over one or more maxima, and finally decline gradually to zero.

If Q be a quantity of a given fuel, and t the time, then

$$P = dQ/dt \tag{1}$$

will be the production rate, where d signifies the amount of change. Then, if the production rate P be plotted on an arithmetic scale as a function of time, as we have done in Figures 8.1 to 8.6, the element of area under the curve with a base of dt and an altitude P, will be

$$dA = Pdt = (dQ/dt)\, dt = dQ. \tag{2}$$

Hence, on such a graph, the cumulative production Q up to any given time t will be proportional to the area between the curve of production rate and the time-axis from the beginning of production until the time t.

For the entire cycle of production, where the production rate begins at zero, and eventually returns to zero, the total area under the curve is a measure of the ultimate amount, Q_∞, of the given fuel produced during the cycle, as is illustrated in Figure 8.8. This fact provides a powerful means of keeping within reasonable limits in our estimations of the future course of the production of a given fuel. If an estimate can be made from geological data of the amount Q_i of the given resource which was initially present in the geographical area considered, then any extrapolation of the production curve for that area must be such that the ultimate area under the curve satisfies the condition

$$Q_\infty \lesseqqgtr Q_i. \tag{3}$$

Mathematically, such a curve may assume an indefinite number of shapes, but the technology of production essentially requires that the early phase be one of a positive exponential rate of increase, and the declining phase an exponential rate of decrease, so between these two requirements, and that of

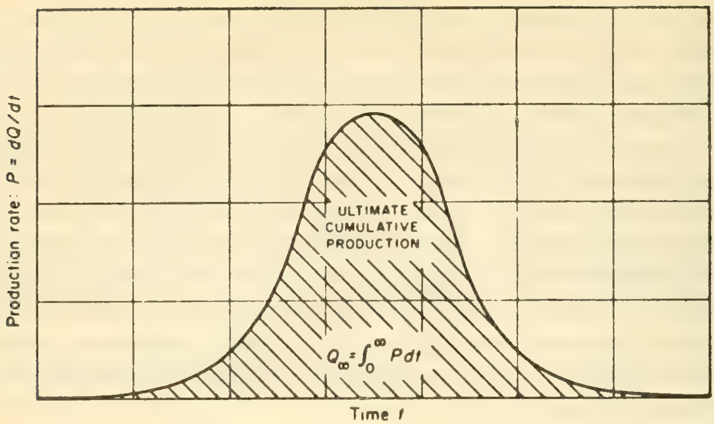

FIGURE 8.8
Full cycle of production of an exhaustible resource. (By permission of the American Petroleum Institute, from *Drilling and Production Practice*, 1956, Figure 11, p. 12.)

the limitation of the area circumscribed, the amount of latitude in such a curve is greatly reduced.

THE PETROLEUM GROUP OF FOSSIL FUELS

Let us first consider the petroleum group of fossil fuels. We have already seen that in just over a century this group of fuels has risen to dominance as the nation's and the world's leading source of industrial energy. Because of this fact, major policy questions resulting from scarcity of resources are likely to arise sooner for petroleum than for coal.

For statistical purposes, the petroleum group of fossil fuels is divided into gaseous, liquid, and solid components. The principal gaseous component is methane of chemical composition CH_4, which is the natural gas of commerce. The principal liquid component is crude oil, which is the stock-tank oil obtained by flow from the underground reservoir rocks by means of oil wells. It ranges all of the way from natural gasolines to very heavy and viscous oils which flow only with difficulty. The principal solid or pseudo-solid components are tars, found in tar sands, and the solid hydrocarbon, kerogen, found in oil shales. Actually, so-called tars are not solids, but viscous liquids whose principal distinction from crude oil is that they cannot be extracted from the ground by means of wells. Kerogen, on the other hand, is a true solid.

A product intermediate between natural gas and crude oil is natural-gas liquid (NGL). Natural-gas liquids, originally known collectively as "casing-head gasoline," constitute a family of hydrocarbons extracted as liquids

during the production of natural gas. In addition to its principal component methane, natural gas also frequently contains diminishing fractions of heavier hydrocarbons of the series of compositions C_nH_{2n+2}, the first five members of which are methane, ethane, propane, butane, and pentane, for which n has the values 1 to 5, respectively. Natural-gas liquids consist of mixtures of propane and heavier components. A subclass of natural-gas liquids is liquified petroleum gases (LPG), consisting principally of mixtures of propane and butane, which are gaseous at atmospheric pressure but liquid at slightly higher pressures. These are familiar as "bottled gas" used for cooking and heating.

Until recent decades, only small amounts of natural-gas liquids were produced in the United States, and prior to 1945 the statistics of this production were lumped with those for crude oil. Since 1945, the annual production of natural-gas liquids and of crude oil have been reported separately. In the meantime, the production rate of natural-gas liquids has increased progressively until by the end of 1967 it amounted to 17.5 percent of the United States production of total liquid hydrocarbons.

As yet, only minor production of solid hydrocarbons has been achieved. Experimental work on the oil shales of Colorado has been under way for about two decades, but large-scale production has not yet begun. The mining of veins of the solid hydrocarbon, gilsonite, in the Uinta Basin of Utah has been in operation for more than a decade, but the reserves are not large. However, successful large-scale exploitation of the large Athabasca tar sands of northeastern Alberta, Canada, was begun in late 1967 by Great Canadian Oil Sands Limited, with a plant having a design capacity of 45,000 barrels of oil per day; other companies are only awaiting approval by the Canadian government to install additional productive capacity.

The production history of crude oil for the world has already been given in Figure 8.2, and of crude oil and natural gas for the United States in Figures 8.5 and 8.6. Were it possible to make reasonably accurate estimates from geological data of the amounts of oil and gas initially present underground, then, by use of the technique described heretofore and illustrated in Figure 8.8, reasonably good approximations of the future of the respective production curves could be made.

Unfortunately, because of the erratic manner in which accumulations of oil and gas occur underground, the problem of estimating the quantities of these fluids still undiscovered by drilling in any given region is difficult. For a preliminary appraisal of the petroleum-producing potentialities of a given region, the only available procedure is geological. Most of the geologists in the world are engaged in exploration for petroleum; and the knowledge of the geology of petroleum, and of the sedimentary basins of the world, that has been accumulated during the last half century is extensive.

In essence, the geological procedure is the following. It is generally agreed

that petroleum is derived from plant and animal debris that was buried in sediments under conditions of incomplete decay during the geologic past. Consequently petroleum is now found only in or immediately adjacent to basins filled with sedimentary rocks. The geographical location and extent of the sedimentary basins in the land areas of the world are now reasonably well known. Sedimentary rocks are porous with an average porosity (ratio of pore volume to total volume) of about 15 to 20 percent. The pores are normally filled with water except where the water has been displaced by oil or gas. Oil and gas, being fluids, are driven by physical forces in this underground rock-water environment into limited regions of space where they are in stable equilibrium. These equilibrium positions are to some degree determinable by detailed studies of the subsurface structure of the rocks, and the associated state of rest or of motion of the water, by geological and geophysical procedures. Oil or gas wells are then drilled in what appears to be the most favorable locations for oil or gas entrapment.

Unfortunately, there is nothing in this procedure that permits better than a crude estimate of the quantity of oil or gas that a given basin may produce. The geological appraisal of the petroleum-producing potentialities of a new territory is carried out largely by analogy with known territories. For example, the geology of the coastal region of Nigeria was found to be similar to that of the coastal region of Texas and Louisiana. By analogy, it was assumed that the Nigerian sediments would probably contain a quantity of oil per unit of volume comparable to that which had already been discovered in the Texas-Louisiana gulf coastal region. Subsequent drilling in Nigeria has confirmed this assumption.

U.S. Crude-Oil Resources

Since the petroleum industry in the United States is the most advanced of that of any major region in the world, the United States experience is commonly used as one of the principal yardsticks in appraisals of the petroleum-producing potentialities of the rest of the world. The difficulty in this procedure, however, lies in the question of how good is the yardstick? How accurately are the undiscovered resources of oil and gas in the United States known? In this regard, it may be mentioned that estimates published within the last 12 years of the ultimate production of crude oil in the United States, exclusive of Alaska, have a fourfold range from about 145 to 590 billion barrels. Corresponding estimates for natural gas have a threefold range from 850 to 2,650 trillion cubic feet.

Estimates of the ultimate amount of crude oil which the world will produce have tended to be roughly proportional to the estimates made by the same authors for the United States.

In view of these circumstances, it is clear that the problem of estimating

petroleum resources of the world is closely linked with the primary problem of estimating those of the United States. For the latter, geological analogy is no longer appropriate. We are left with the problem of a direct estimation, and this can only be based on the cumulative experience which is condensed into the statistics of exploration, drilling, discovery, and production of the petroleum industry in the United States. A problem of comparable or even greater importance is that of estimating the degree of advancement that the U.S. petroleum industry has reached in its evolutionary cycle. For these purposes two procedures have been evolved which yield reasonably unambiguous results (Hubbert, 1962, p. 50–65; 1967).

The first of these concerns the relationship between cumulative production, Q_p, cumulative proved discoveries, Q_d, and proved reserves, Q_r. Statistics on annual production of crude oil in the United States are available since 1860, and, from these, cumulative production up to any given year can be computed. Estimates of proved reserves of crude oil at the end of each year have been made annually by the reserves committee of the American Petroleum Institute (API) since 1937, and the series of proved reserves, based on older estimates, has been extended by the API statistical staff back to 1900. Cumulative proved discoveries up to any given time may be defined to be the sum of all of the oil produced up to that time plus the proved reserves. Hence, if we know the cumulative production and the proved reserves for any given time, the cumulative discoveries may be given by the equation

$$Q_d = Q_p + Q_r. \tag{4}$$

The corresponding rates of discovery are given by

$$dQ_d/dt = dQ_p/dt + dQ_r/dt, \tag{5}$$

in which the three terms represent the rates of discovery, of production, and of the increase of proved reserves, respectively.

From the principles previously set forth, we already know the general properties of each of the quantities in equations (4) and (5), when plotted graphically as a function of time. The production rate dQ_p/dt must begin at zero, increase to one or more maxima, and ultimately return to zero. The integral of this curve, the cumulative production Q_p, must begin at zero and then increase at an exponential rate as long as the production rate so increases. Then, when the production rate reaches its maximum value, the curve of Q_p will have its maximum slope. Finally, as the production rate declines, the Q_p-curve will gradually approach an ultimate quantity Q_∞, which represents the ultimate amount of oil produced during the entire cycle. The cumulative curve will accordingly exhibit the familiar S-shape common to growth phenomena. It can only increase with time, and it is asymptotic to zero at the beginning and to Q_∞ at the end.

The curve of proved reserves plotted against time has a different shape. At the beginning of production proved reserves are zero, and again at the end. The proved-reserves curve over the entire cycle must accordingly begin at zero, increase to a maximum, and then decline to zero.

From equation (4) it follows that the cumulative-discovery curve must resemble that for cumulative production except that discoveries must precede production by some time interval, Δt. At the end of the cycle, when $Q_r = 0$, the value of Q_d must be the same as Q_p. Hence both the Q_d- and the Q_p-curves must approach the same ultimate value Q_∞.

Strictly, the foregoing relations apply for a single-cycle growth curve. For oil production in a small area—the State of Illinois for example—there may be multiple cycles of production. For the whole United States, small local variations superpose and cancel one another out. Accordingly, all present evidence indicates that in this case we are dealing with but a single major cycle of discovery and production.

The general forms of the three curves of Q_d, Q_p, and Q_r, for a single growth cycle, are those shown in Figure 8.9. Corresponding curves of the rate of discovery, of production, and of increase of proved reserves, are shown in Figure 8.10. On these curves, one point is worthy of note. When the proved-reserves curve in Figure 8.9 reaches its maximum value, its slope, dQ_r/dt, which is the rate of increase of proved reserves, becomes zero. Then at this time equation (5) becomes

$$dQ_d/dt = dQ_p/dt. \tag{6}$$

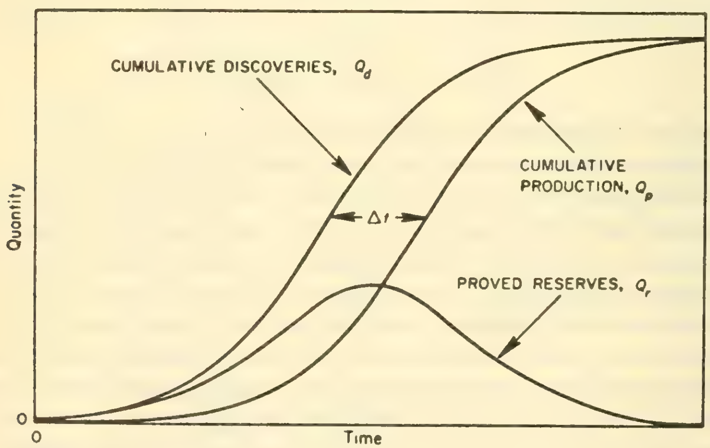

FIGURE 8.9
Generalized form of curves of cumulative discoveries, cumulative production, and proved reserves for a petroleum component during a full cycle of production. Δt indicates the time lapse between discovery and production. (From Hubbert, 1962, Figure 22, p. 55.)

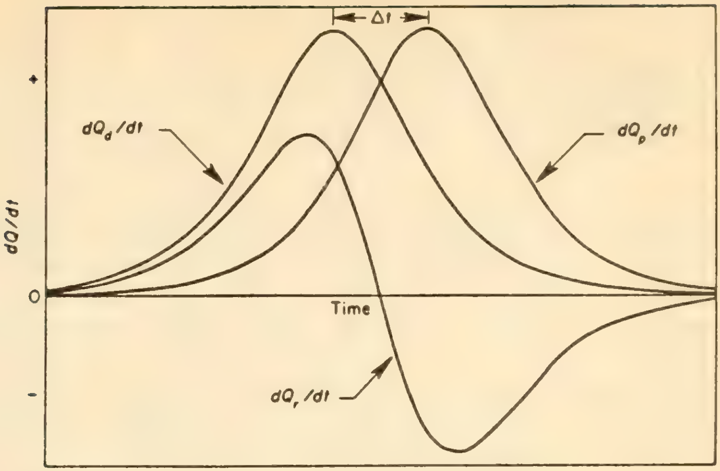

FIGURE 8.10
Relations between rate of production (dQ_p/dt), rate of proved discovery (dQ_d/dt) and rate of increase of proved reserves (dQ_r/dt) during a full cycle of petroleum production (From Hubbert, 1962, Figure 24, p. 56.)

This indicates that at the peak of proved reserves the curves of the *rate* of production and the *rate* of discovery cross one another, with the production rate still rising but the discovery rate already on its decline. The time at which this occurs is roughly halfway between the peaks in the discovery rate and the production rate. The study of the actual data of the U.S. petroleum industry in the light of these relationships can be very informative.

The data of U.S. cumulative discoveries, cumulative production, and proved reserves of crude oil, exclusive of Alaska, are shown graphically in Figure 8.11. The discontinuity at 1945 is caused by the separation, starting at that time, of natural-gas liquids data from crude oil data. The time delay, Δt, between cumulative discovery and cumulative production is shown in Figure 8.12. This is obtained by tracing the Q_d-curve and sliding it parallel to the time axis until it most nearly matches the Q_p-curve. For the last decade, as seen in the figure, this time-delay, Δt, has been about 12 years. Earlier, it would have been somewhat less, about 10–11 years. What is most significant is that for the last 40 years the curve of cumulative production has faithfully followed that of cumulative discoveries with a time delay rarely outside the range of 10–12 years. In consequence of this relationship, the Q_d-curve acts as about a 12-year preview of the behavior of the Q_p-curve In other words, the state of crude-oil production 12 years from now will probably not differ greatly from the state of discovery at present.

The proved-resources curve in Figure 8.11 is plotted on too small a scale to show all of its significant detail. It is accordingly replotted on a magnified scale in Figure 8.13. From this it may be seen that a smooth curve

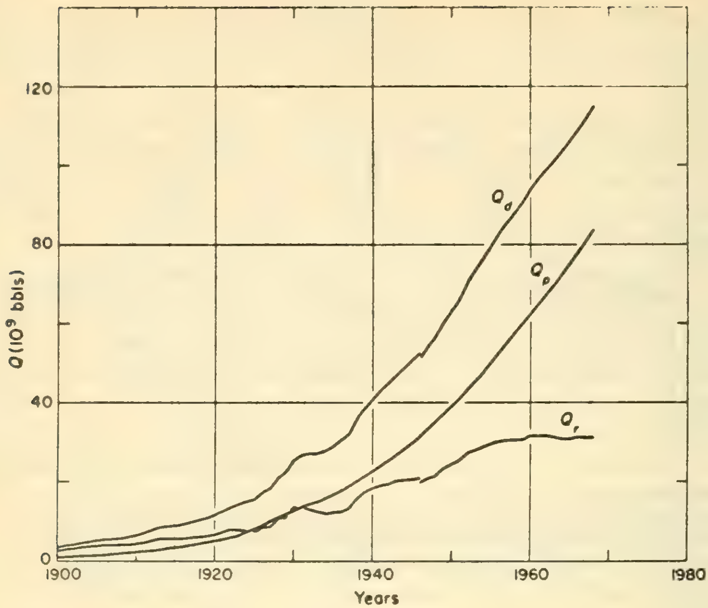

FIGURE 8.11
Data for the United States, exclusive of Alaska, on cumulative production (Q_p), cumulative proved discoveries (Q_d), and proved reserves (Q_r) of crude oil.

approximating the actual curve would have its maximum value at about 1961. This becomes even more clear in Figure 8.14, representing the rate of increase of proved reserves. The dashed-line curve represents the computed value of dQ_r/dt from an analytical curve approximating the actual proved-resources curve. The solid-line zig-zag curve represents the actual year-to-year data of increase of proved reserves. From the general form of the proved-resources curve, its slope, or rate of increase, must have a positive loop while reserves are increasing, and a negative loop while decreasing, and the curve must cross the zero line from the positive to the negative loop at the time when reserves reach their maximum value. From Figure 8.14 it can be seen that this cross-over also occurred about 1961. As evidence that this is not merely a temporary aberration, it may be noted that the rate-of-increase curve reached the maximum of its positive loop about 1942 and the actual year-to-year data, with only minor oscillations, have declined steadily since 1951.

Data of the rates of discovery and of production of crude oil in the United States are shown in Figure 8.15. As in the case of Figure 8.14, the dashed-line curves are analytical derivatives of smooth curves fitting the cumulative discovery and cumulative production curves of Figure 8.11. The solid line zig-zag curves are the actual yearly data. The maximum rate of discovery,

according to the analytical curve, would have been about 1957. In the figure, a time-delay, Δt, of 10.5 years is shown between discovery and production. However, during the last decade the delay averaged about 12 years. Accordingly, the peak in the rate of production, which should lag behind that of discovery by about the same time interval, should be expected to occur about 1969 plus or minus a year or two.

Strictly speaking, this peak in the rate of production refers to the smooth analytical curve rather than to that of the actual year-to-year production oscillations. Since the actual production rate is somewhat less than the productive capacity of the country, it is possible that an all-time peak in the oil produced during a single year might occur during any given year within a time interval of five years or more. The data of Figures 8.11 to 8.15 are consistent in indicating that the U.S. petroleum industry, exclusive of Alaska, is now (1969) in the region of its all-time maximum rate of production, but it will probably not be possible to assign an accurate date to this event until about five years after it has happened.

Another result obtainable from the data in Figures 8.11 to 8.15 is an estimate of the magnitude of Q_∞, the ultimate amount of oil to be produced.

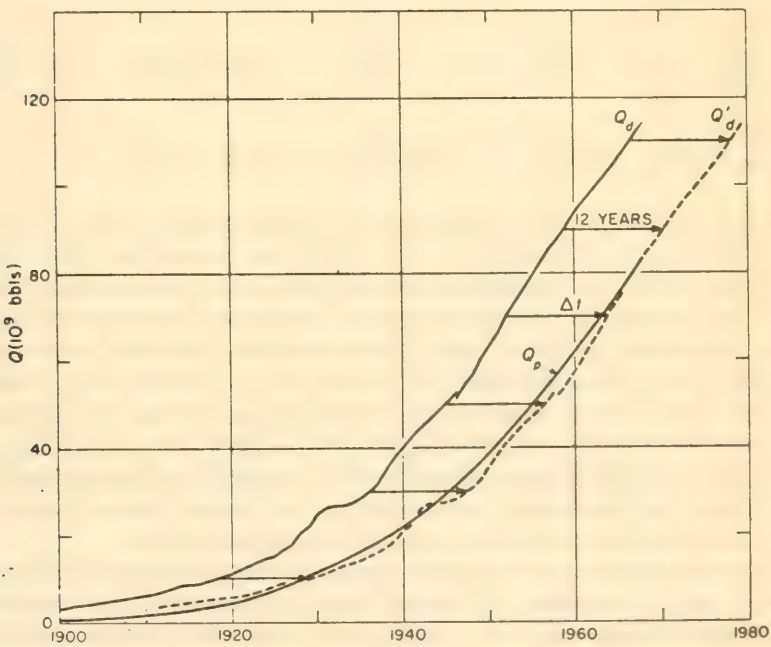

FIGURE 8.12
Time delay, Δt, between United States cumulative proved discoveries (Q_d) and cumulative production (Q_p) of crude oil. The dashed line Q'_d reflects the form of the curve Q_d when it is slid to the right, parallel to the time axis, until it most nearly matches the curve Q_p.

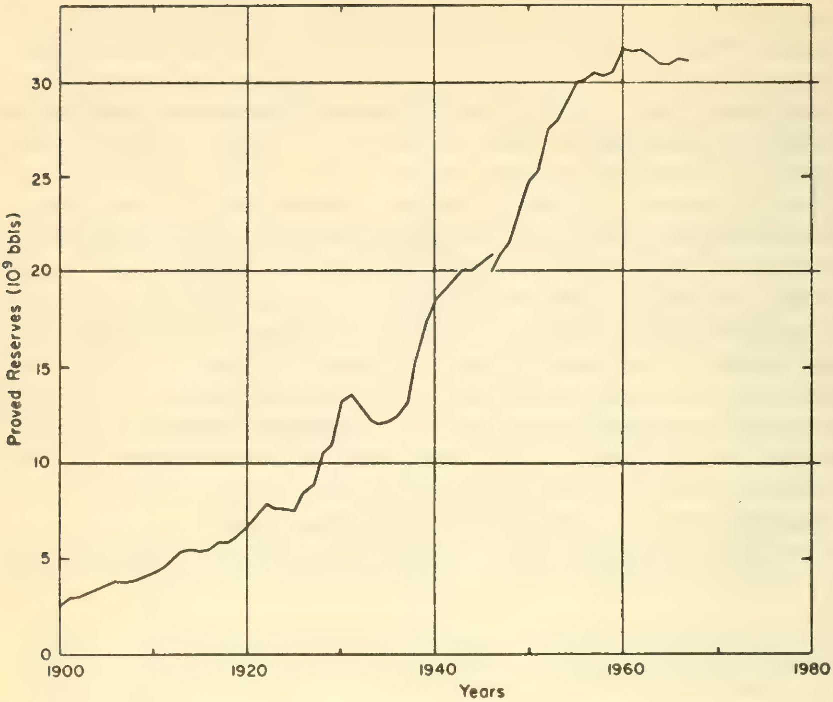

FIGURE 8.13
Proved reserves of crude oil in the United States, exclusive of Alaska

If we assume that peak rates in discovery and in production occur at about the halfway points of cumulative discoveries and production, then each of these curves will give an estimate for the value of Q_∞. At the beginning of 1957, the approximate date of the peak in the proved-discovery rate, cumulative discoveries amounted to 85.3 billion barrels. Twice this would give a figure of 170.6 billion barrels as an estimate for Q_∞. During the last decade, the time delay Δt of production with respect to discovery has averaged about 12 years. If we take the beginning of 1969 (12 years after the peak in the discovery rate) as the approximate date of the peak in the production rate, the cumulative production will be about 86.5 billion barrels. Twice this amount would give a value of 173.0 billion barrels for Q_∞.

It is to be emphasized that these figures are only approximate, since in either case it is possible that the peak rates of discovery or of production could occur somewhat earlier or somewhat later than the halfway points.

While the foregoing procedures are especially well suited for the determination of such critical dates as the peaks in the rates of discovery and production, and of that of proved reserves, they are somewhat less reliable as a means of estimating the ultimate amount of oil Q_∞ that will be produced.

For the latter purpose, a much better procedure has been developed; it was suggested by the studies of A. D. Zapp (now deceased) of the United States Geological Survey (Zapp, 1962, pp. H-22–H-33). The procedure is to express the rate of discovery in terms of barrels of oil discovered per foot of exploratory drilling, and then determine how this rate varies as a function of the cumulative footage of exploratory drilling. In this system of coordinates, if Q is the quantity of oil discovered, and h the cumulative footage drilled, then the rate of discovery dQ/dh would be plotted as the vertical coordinate in bbls/ft against cumulative footage, h, as the horizontal coordinate.

This system is mathematically analogous to that which we have used heretofore where the time-discovery rate dQ/dt has been plotted against cumulative time t. In both systems of coordinates, the area under the curve represents cumulative discoveries up to the cumulative depth h, or the cumulative time t, respectively. The former has several advantages over the latter, however. In the first place, the rate of discovery per foot depends principally on technological factors and is relatively insensitive to economic

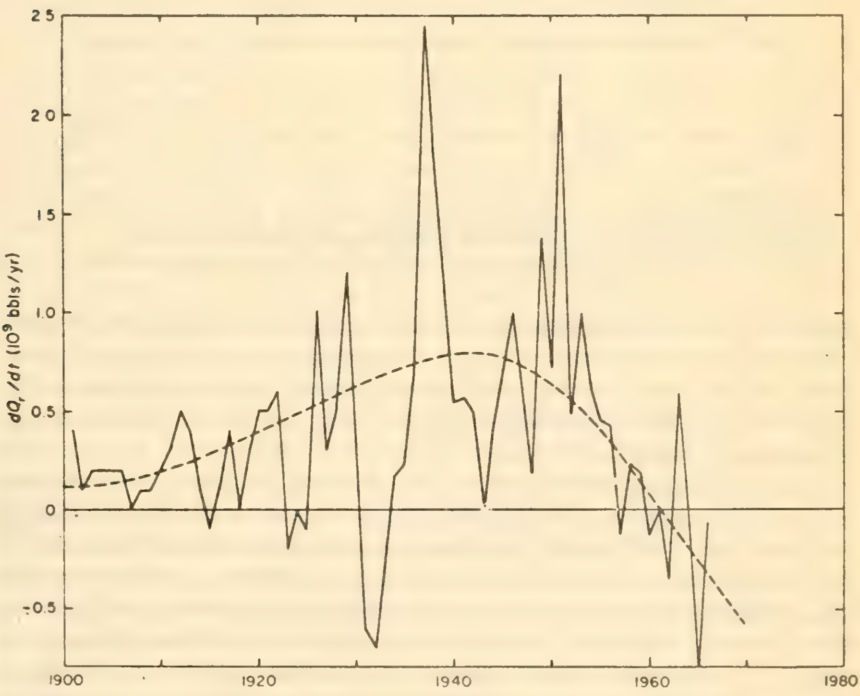

FIGURE 8.14
Rate of increase of proved reserves of crude oil in the United States, exclusive of Alaska. Solid line shows actual year-to-year increase in proved reserves, dashed line the computed rate of increase dQ_r/dt.

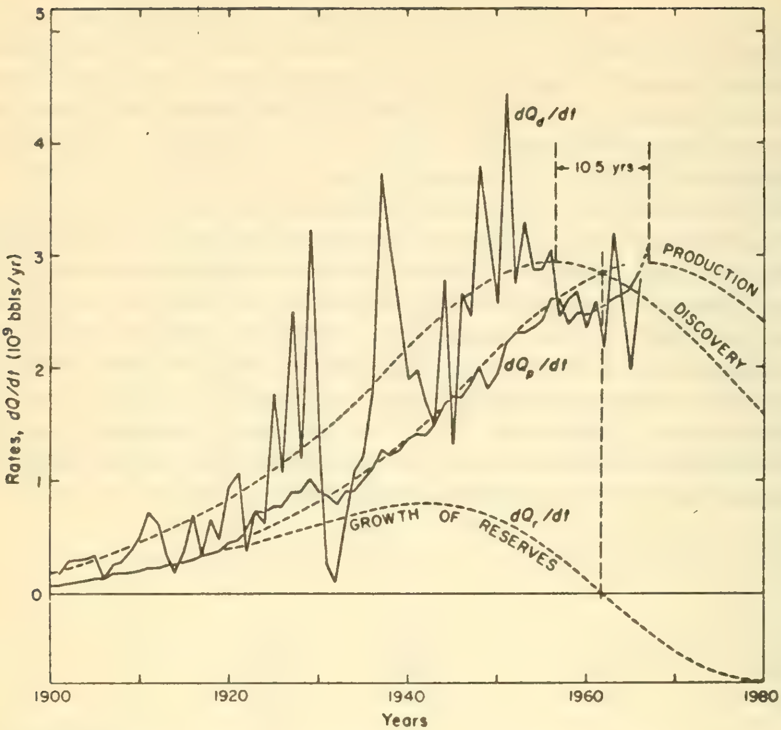

FIGURE 8.15
Rates of proved discovery (dQ_d/dt), production (dQ_p/dt), and increase (dQ_r/dt) of reserves of crude oil in the United States, exclusive of Alaska. Dashed line curves are analytical derivatives, solid lines are actual yearly data.

conditions. The rate of discovery per year, on the contrary, can swing widely from one year to the next in response to economic and political conditions. In the second place, a practical limit can be set to the ultimate amount of cumulative exploratory drilling in a given area, whereas no such limit can be assigned to cumulative time.

Although Zapp did not develop this method, its main features were implied in his important paper, "Future Petroleum Producing Capacity of the United States" (Zapp, 1962), whose principal results can only be presented graphically in this system of coordinates. This method thus permits not only a graphical presentation of the Zapp estimates, and of others based on the same premises, but it also permits an easy verification of those premises by means of petroleum-industry statistical data. And, more important, it permits a direct evaluation of the discovery history of the U.S. petroleum industry up to the present, and a more reliable appraisal of its future than has been obtainable previously.

Therefore, instead of reviewing initially the estimates of the ultimate

amounts of crude oil which the United States may produce (estimates that have been made by Zapp and others) and the premises on which they have been based, it will be more economical for us to proceed directly with our own analysis of the data. What we seek is the curve of oil discovered per foot of exploratory drilling as a function of cumulative footage from the beginning of the industry to the present. Then, on the basis of this information—whether the curve is still rising, remaining stationary, or declining—we can make some prognostications on ultimate crude-oil production. This study has in fact already been made and published (Hubbert, 1967) and only its principal results will be summarized here.

To obtain the desired result, we must first work with the statistical data published by years. We thus require estimates of the oil discovered each year and of the footage of exploratory drilling each year. The ratio of these quantities then gives the oil discovered per foot *as a function of time*. By adding cumulatively the drilling footage, as a function of time, we are then able to determine the quantity of oil, ΔQ, discovered for each successive equal increment, Δh, of cumulative footage, and this ratio, $\Delta Q / \Delta h$, versus h will be a finite approximation to the desired curve.

For discoveries assignable to a given year, we require a different definition of discoveries from that of *proved discoveries* used heretofore. For this purpose, we adopt a procedure initiated by the Petroleum Administration for War (PAW) (Frey and Ide, 1946) in a study as of 1945, and continued in successive similar studies by the National Petroleum Council (NPC, 1961, 1965) and, finally, jointly by the American Gas Association (AGA), American Petroleum Institute (API), and Canadian Petroleum Association (CPA) (AGA, API, and CPA, 1967), in which all of the oil contained in any given field is credited to the year of discovery of the field. Studies have been made on this basis and estimates published as of January 1 for the years 1945, 1960, 1964, and 1967.

In these studies, the oil credited to a given year, as of a later date, consists of the sum of the cumulative production up to the date of the study plus the estimated proved reserves, of all of the fields discovered in the given year. However, by the rules of the API reserves committee, proved reserves at any given time are not intended to represent all of the oil that will eventually be produced by the fields already discovered at that time. Rather, they represent a working inventory of oil that is present and producible by wells and equipment already in operation. Additional reserves are added as the fields are developed.

For this reason, the oil discoveries ascribed to any given year, based in part on the API reserves estimates, gradually increase with time. This effect was studied (Hubbert, 1967), and on the basis of the successive published estimates, the *ultimate* amount of oil that the fields discovered each year since 1860 would produce was estimated. This involved negligible

additions over the recent NPC estimates for fields discovered more than 50 years ago, but required progressively larger additions (up to 5.8-fold) as the year of discovery approached the present.

In this manner, the cumulative proved discoveries, computed on the basis of the NPC studies and brought up to 1 January 1967, amounted to 111.7×10^9 bbls for the United States exclusive of Alaska. The estimated ultimate production of the fields already discovered amounted to 136.2×10^9 bbls, an increase of 24.5×10^9 bbls.

For the feet of exploratory drilling per year, and cumulative exploratory footage, drilling statistics are available intermittently from 1927 to 1944 and annually since 1945. For the earlier periods, statistics exist on the total number of wells drilled per year, classified as oil wells, gas wells, and dry holes. During the period since exploratory well statistics have become available, the number of exploratory wells drilled has averaged about 0.67 of the total number of dry holes. Assuming that about the same ratio prevailed during earlier drilling, the approximate number of exploratory wells could be estimated from the dry-hole data. Then, to obtain the footage per year, the number of exploratory wells was multiplied by the estimated average depth. The latter is known approximately from the known depths of the fields discovered at successive times.

The net result of this study was that by 1 January 1967, the estimated cumulative footage of exploratory drilling amounted to 15.2×10^8 feet. This divides conveniently into 15 units of 10^8 feet for each of which the oil discovered, ΔQ, can be evaluated from previous discovery data, and the average discoveries per foot, $\Delta Q/\Delta h$, determined.

The results are shown in Figure 8.16. During the first 10^8-ft interval of drilling, which extended from 1859 to 1920, the average oil discovery rate was 194 bbls/ft. During the second interval, from 1920 to 1928, the rate dropped to 167 bbls/ft. Then, during the third interval, extending from 1928 to 1937 and including the discovery of the East Texas oil field, the discovery rate reached an all-time peak of 276 bbls/ft. Following this, the rate has fallen precipitately to a present level of about 35 bbls/ft.

This decline during the 30-year period since 1937 is particularly significant in view of the fact that the oil credited with having been discovered during this period represents the cumulative results of all of the advances in the techniques of exploration and production of the petroleum industry during its entire history up to 1967. This also was the period of the most intensive research and development in exploratory and production techniques in the history of the industry. The observed decline in the rate of discovery during this period is, accordingly, difficult to account for on any other basis than that undiscovered oil is becoming scarce.

The tops of the columns in Figure 8.16 represent approximately the curve of dQ/dh versus h, and the area under this curve represents cumulative

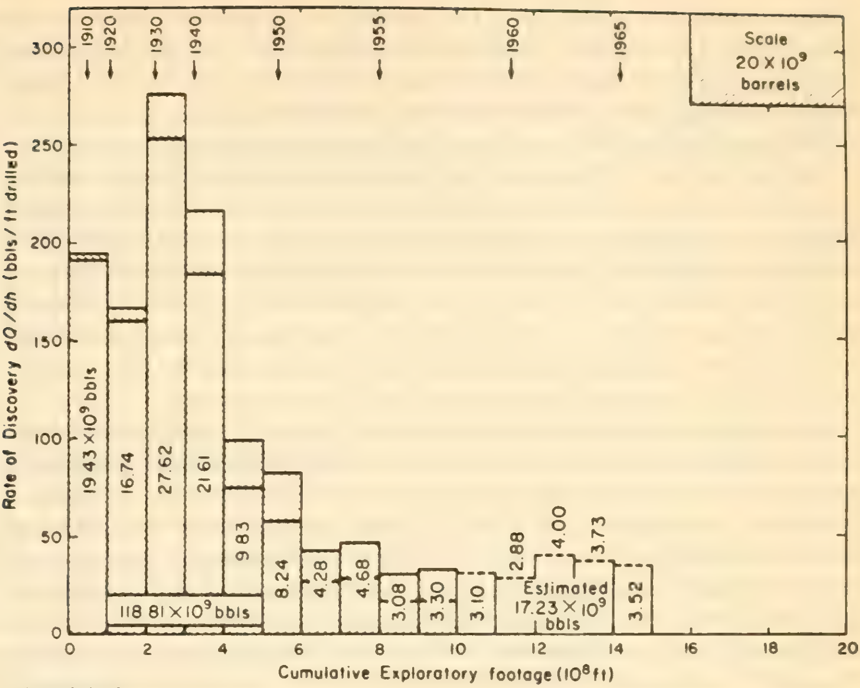

FIGURE 8.16
Crude-oil discoveries per foot of exploratory drilling versus cumulative exploratory footage in the United States, exclusive of Alaska, 1860–1967. (By permission from *Bulletin of American Association of Petroleum Geologists*, 1967, vol. 51, Figure 15, p. 2223.)

discoveries. Future discoveries can accordingly be estimated by extrapolating the decline curve of Figure 8.16, and computing the additional oil corresponding to the added area. In the study cited (Hubbert, 1967), this was done using two different negative-exponential rates of decline, the first an approximate average for the whole period, and a second slower rate from 194 bbls/ft for the first column to 35 bbls/ft for the last. The faster rate of decline gave 153×10^9 bbls as an estimate of Q_∞, and the slower rate, 164×10^9 bbls.

It will be noted, however, that during the last seven 10^8-ft units of drilling, the discoveries per foot have remained nearly constant. The reason for this is twofold. The time required for these last seven units of drilling was only the 12-year period from 1955 to 1967. This was the period during which the rate of exploratory drilling decreased sharply from an all-time peak of 16,207 wells in 1956 to 10,275 (excluding Alaska) in 1966. Since the highest-grade prospects are customarily drilled in preference to those of lower grade, a reduction in the number of wells drilled in a given year tends to increase the average grade of the prospects drilled, and hence to improve

the rate of discovery per foot. The second, and principal reason for the slowdown in the decline of the discovery rate per foot, however, is that this was also the period during which most of the large discoveries were made, with a minimum of exploratory drilling, in offshore Louisiana.

Because these two effects are both intrinsically temporary, the slowdown in the decline rate of discoveries per foot during the last 12 years must be regarded as only a temporary episode in a long-term trend of decline. However, even in the improbable event that the discovery rate could be held constant at the present rate of 35 bbls/ft and the drilling rate also maintained at the 1967 level of 49×10^6 ft/yr, until the year 2000, the new oil discoveries would amount to but 57 billion barrels. When this is added to the 136 billion barrels already discovered by the beginning of 1967, the total by the year 2000 would still amount only to 193 billion barrels.

Independent confirmation of this long-term decline in the rate of discovery with cumulative drilling is afforded by the statistics published annually by the Committee on Statistics of Drilling of the American Association of Petroleum Geologists. Each year this committee reports on the number of new-field wildcat wells that were required 6 years previously to make one profitable discovery of either oil or gas. A profitable discovery is defined as 1 million barrels of oil or an equivalent amount of oil plus gas. In 1945, the first year of the series, 26 new-field wildcat wells were required per profitable discovery; by 1961, the last year of the series, this number had increased to 70 wells per discovery. (Dillon and Van Dyke, 1967, p. 994, Fig. 9; Van Dyke, 1968, p. 918, Fig. 9).

Hence, on the basis of the results shown in Figure 8.16, the highest figure that at present can be justified for Q_∞, the ultimate amount of oil to be produced by the conterminous part of the United States and its adjacent continental-shelf areas, is about 165×10^9 bbls. Of this, the amount of 136 $\times 19^9$ bbls, or 83 percent, is accounted for by fields already discovered, leaving but 17 percent for fields still to be discovered.

The absolute value of Q_∞, for these same fields, could be increased above the figure of 165×10^9 bbls, should a drastic improvement in the efficiency of recovery from the oil in place be effected. Even in this case, however, the improvement would involve the fields already discovered to the same degree as those still to be discovered so that the ratio of oil already discovered to that still to be discovered would remain essentially unchanged.

Offsetting any expectancy of a drastic improvement of the present recovery efficiency of somewhere near 40 percent are the following facts: (1) Every technique of improved recovery efficiency so far devised by petroleum-industry research is already in operation to about its economic limit. (2) More expensive procedures could be justified only by a corresponding increase in the price of oil. The latter, however, is precluded by the fact that should domestically-produced oil become more expensive, the

public has access to alternate sources of less expensive liquid fuels, obtainable both from imports and from oil shales and coal.

The figure of 165×10^9 bbls is accordingly the best present estimate of the value of Q_∞ for the conterminous United States, although it is admitted that a somewhat higher figure resulting from further improvement in recovery efficiency is a physical possibility.

Having obtained the estimate of $Q_\infty = 165 \times 10^9$ barrels for the crude-oil production in the conterminous United States, we are now in a position to plot the complete cycle of production, utilizing the principle illustrated in Figure 8.8. This is shown in Figure 8.17 of which one grid square has the dimensions

$$10^9 \text{ bbls/yr} \times 20 \text{ yrs} = 20 \times 10^9 \text{ bbls.}$$

Hence, if the figure of 165×10^9 barrels is approximately correct as a value for Q_∞, the total area under the curve can contain only $8\frac{1}{4}$ of the grid squares of the figure. The area to the left of the vertical line at the year 1934 represents a cumulative production of 16.5×10^9 barrels, or the first 10 percent of Q_∞; the area to the right of the vertical curve at the year 1999 represents the last 10 percent. The area under the curve between these two dates represents the middle 80 percent of Q_∞. Hence, the time that will be required to produce and consume the middle 80 percent of the ultimate amount of crude oil to be produced in the conterminous United States is only about 65 years, or less than a single lifetime.

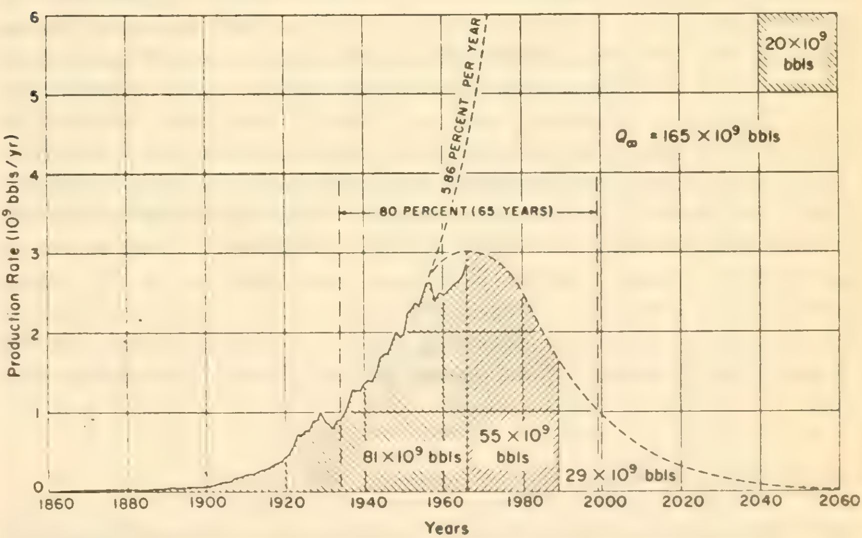

FIGURE 8.17
Complete cycle of crude-oil production in the United States and adjacent continental shelves, exclusive of Alaska.

The dashed-line curve in Figure 8.17 shows what the production rate would have been after 1955 had the rate of growth that prevailed from 1935 to 1955 continued.

In this estimate, Alaska has been excluded because it represents a large, almost virgin territory which has not yet developed far enough to contribute to the statistics on which the foregoing analysis has been based. Significant Alaskan oil production was begun in the Kenai-Cook Inlet area only as recently as 1958, with cumulative proved discoveries by 1 January 1968, amounting to 0.474 billion barrels, with an estimate of about 1 billion barrels of ultimate production.

Also, a very large oil discovery has been announced (*Oil and Gas Journal*, 22 July 1968, p. 34–35), near Prudhoe Bay on the Alaskan North Slope, which, according to a report by the consulting firm of DeGolyer and McNaughton, promises to be in the 5 to 10 billion-barrel class. This would make it equal to or larger than the East Texas field—the largest in the United States thus far—and comparable to the world's largest fields in the Middle East.

Aside from these developments, the Alaskan potentialities for petroleum production can at present be based only on comparisons by means of geological analogy. According to Hendricks (1965, p. 7) the total potential oil-producing area of the United States, including Alaska, and adjacent continental-shelf areas, is just over 2 million square miles; and for the United States minus Alaska, 1.86 million square miles. This would give for Alaska a potentially productive area of about 0.14 million square miles, or an area equal to 7.5 percent of that of the rest of the United States. If we use the crudest type of comparison (which could easily be wrong by a factor of 2 or more), we may assume that Alaska will produce as much oil per square mile of potentially productive area as the rest of the United States. This would give for Alaska a potential production of about 12 billion barrels.

As a consequence of the new Prudhoe Bay discovery, this figure appears to be too low. Even so, a provisional allowance of 25 billion barrels for the ultimate crude-oil production of Alaska is about as large a figure as can be justified from present evidence. This figure, when added to the 165 billion barrels for the remainder of the United States, gives 190 billion barrels as our present estimate of the approximate amount of crude oil ultimately to be produced by the whole United States and its adjacent continental shelf areas.

Estimates by Others

As we have remarked earlier, estimates published within the last 12 years of the ultimate amount of crude oil to be produced within the United States and its adjacent continental shelves, exclusive of Alaska, have had a fourfold

range from 145 to 590 billion barrels. Estimates in the higher range fall into two principal groups: (1) estimates based on the Zapp hypothesis, or its modification, and (2) estimates based on geological analogy.

Production estimates based on the Zapp hypothesis (p. 177), or its modification, include: 590 billion barrels of crude oil for the United States, exclusive of Alaska (Zapp, 1961); 650 billion barrels, presumably including Alaska (McKelvey and Duncan, 1965); and 400 billion barrels, including Alaska (Hendricks, 1965). Since these have already been analyzed in detail in a recent paper (Hubbert, 1967), only brief comment regarding them will be made here.

The Zapp hypothesis, in the form that produced the above estimates, is based on the assumption that the oil to be discovered per foot of exploratory drilling in any given petroliferous region will remain essentially constant until an areal density of about one exploratory well per two square miles has been achieved. The nature of this hypothesis, as formulated by Zapp (1962, pp. H-22 H-23) for the conterminous United States as of the year 1959, is shown graphically in Figure 8.18.

In this, only percentages of ultimate exploration were given. Later (after the foregoing report was written, but before its publication), Zapp (1961) estimated that by 1961, about 130 billion barrels of crude oil had already been discovered in the United States by about 1.1 billion feet of exploratory drilling. This would have been at a rate of 118 bbls/ft. He also estimated that the cumulative footage required by a density of one well per two square miles, drilled either to the basement or to 20,000 feet, in the United States would amount to 5 billion feet, and that by such drilling 590 billion barrels of producible crude oil would be discovered. This corresponds to the maintenance of an average discovery rate of 118 bbls/ft for the entire 5 billion feet of drilling.

A simple test of the validity of this hypothesis can be made by determining whether or not the discoveries per foot made by past exploratory drilling have remained approximately constant. This we have done, and the results, which are given in Figure 8.16, show unequivocally that the Zapp hypothesis

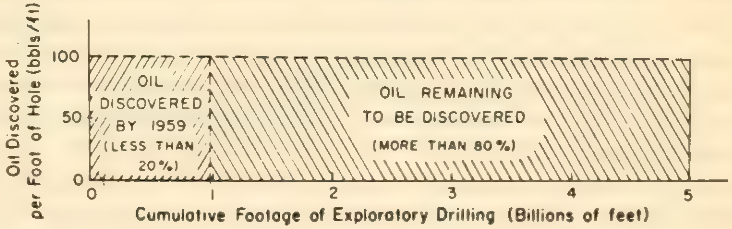

FIGURE 8.18
The Zapp hypothesis of the rate of oil discoveries per foot of exploratory drilling versus cumulative footage.

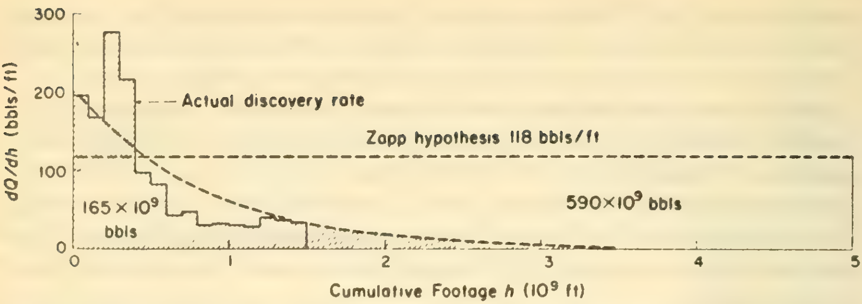

FIGURE 8.19
Comparison of Zapp hypothesis with actual United States discovery data from Figure 8.16.

in this simple form is untenable. Instead of remaining constant, discoveries per foot have fallen drastically during the last 35 years from a maximum value of 276 bbs/ft during the period 1928–1937 to a present figure of about 35 bbls/ft. In Figure 8.19 the data of Figure 8.16 are shown superposed on the rectangle generated by the Zapp hypothesis of a constant discovery rate of 118 bbls/ft. From this, it is evident why the estimate derived deductively from the Zapp hypothesis is about 3.5 times the highest figure of about 165 billion barrels that can be justified by the discovery data—an over-estimate of about 425 billion barrels.

Consequently, since the Zapp hypothesis is not compatible with petroleum-industry data and leads consistently to figures that are much too high, estimates obtained by the use of that hypothesis in the form applied must be discounted.

Of the higher range of estimates based on geological premises and analogy, among the most notable are those by L. G. Weeks (1948; 1950; 1958; 1959), formerly a geologist of Standard Oil Company of New Jersey, and now a consultant. In 1948, Weeks gave a summary estimate, based on the technology and economics of that date, of 110 billion barrels as the ultimate amount of crude oil to be produced on the land areas of the United States. In 1958, he increased this to 240 billion barrels of "liquid petroleum" for both the land area and the adjacent continental shelves. When corrected for natural-gas liquids, this would reduce to about 200 billion barrels of crude oil. Then, in the following year (1959), he increased this estimate to 460 billion barrels of liquid petroleum, which would correspond to about 380 billion barrels of crude oil.

As to how these estimates were made, Weeks has remained consistently unclear. The figures apparently are to be accepted on the authority of the author's extensive knowledge of petroleum geology. Moreover, for the 11-year period from 1948 to 1959, for which Weeks more than tripled his estimate, there was no commensurate increase in the knowledge of the

petroleum geology of the United States. It is, therefore, not possible to appraise the reliability of Weeks' estimates in terms of the methods used; they can only be checked against other sources of information. By this criterion, it appears that Weeks' earlier estimate of 110 billion barrels for the land area is more reliable than his later estimates. For, if to the figure of 110 billion barrels for the land area, we add a liberal additional 20–30 billion barrels for the adjacent continental shelves and another 25 billion barrels for improvements in exploratory and production techniques, we obtain an estimate in the range of 155 to 175 billion barrels, which is consistent with other present information. No justification, geological or otherwise, has yet been found for Weeks' more recent, much higher estimates.

Natural-Gas Resources of the United States

The rate of production of natural gas in the United States has been shown in Figure 8.6. As in the case of crude oil, we require an estimate of the ultimate quantity, Q_∞, of natural gas that the United States and adjacent continental shelf areas, exclusive of Alaska, may be expected to produce before we can construct a curve of the complete cycle of production.

The problem of estimating Q_∞ for natural gas is essentially the same as that for crude oil. However, because of the close genetic relationship between natural gas and crude oil, a good approximation of Q_∞ for gas can be obtained from the results of the analysis for crude oil which has already been given. We have seen that by 1 January 1967, the ultimate amount of crude oil that the fields already discovered in the conterminous United States are estimated to produce is taken to be 136 billion barrels, leaving 29 billion barrels for future crude-oil discoveries.

During the last 20 years, the ratio of natural-gas discoveries in the United States to those of crude oil have averaged about 6,000 ft^3/bbl.

Making a liberal assumption of 7,500 ft^3/bbl for the gas-oil ratio of future gas discoveries, we would then obtain an estimate of 218 trillion cubic feet for the gas to be discovered while the 29 billion barrels of future crude-oil discoveries are being made.

By 1 January 1967, the cumulative proved discoveries (cumulative production plus proved reserves) of natural gas in the conterminous United States amounted to 604 trillion cubic feet and the proved reserves alone to 286 (AGA, API, and CPA, 1967). In our previous study of crude oil, we found an estimated 24.1 billion barrels of producible crude oil in fields already discovered in excess of the 31.1 billion barrels of proved reserves. Assuming that about the same ratio prevails for natural gas, we obtain a figure of 222 trillion cubic feet for the fields already discovered beyond the 286 trillion cubic feet of proved reserves.

Then, adding these three figures, we obtain a rough estimate for the ultimate amount of gas Q_∞:

	$(10^{12}ft^3)$
Proved discoveries, as of 1-1-67	604
Additional gas in already discovered fields	222
Future discoveries	218
Total Q_∞	1,044

This figure is in close agreement with the estimate of 1,000 trillion cubic feet obtained from different data in the National Academy of Sciences report on *Energy Resources* (Hubbert, 1962, pp. 75–80) of 1962. It is much less than the Zapp (1961) estimate of 2,650 trillion cubic feet, and the Hendricks (1965) estimate of about 2,000 trillion cubic feet, including Alaska, or about 1,800 trillion cubic feet, excluding Alaska.

An estimate of a totally different character has recently become available as the result of the work of an industry committee, the Potential Gas Committee, under the chairmanship of B. Warren Beebe. At its meeting in Vancouver on 15–17 September 1967, the Committee on Resources and Man received from Beebe a confidential preview of a forthcoming report of the Potential Gas Committee.

This committee is made up of about 200 members from the oil and gas industry. It consists of a central committee, and 15 separate regional committees whose members are chosen on the basis of their extensive knowledge of the region concerned. The committee is a continuing committee and plans to revise its estimates at two-year intervals. Beginning at the local level, and using confidential information from the petroleum-industry files, local estimates are made, which are then assembled into regional estimates and these, finally, into an estimate for the whole conterminous United States.

The report of the Potential Gas Committee, released in October 1967, presents the following estimate of the natural-gas situation of the United States, exclusive of Alaska and Hawaii, as of 31 December 1966:

	$(10^{12}ft^3)$
Cumulative past production	314
Proved reserves	286
Total proved discoveries	600
Potential supply	690
Ultimate supply	1,290

The total potential supply of 690 trillion cubic feet is the sum of the following amounts of gas classified according to decreasing probability of discovery:

	$(6^{12}ft^3)$
Probable	300
Possible	210
Speculative	180
Total Potential Supply	690

A minor discrepancy exists between the Potential Gas Committee's figure of 600 trillion cubic feet for cumulative proved discoveries up to the beginning of 1967, and the figure of 604 trillion cubic feet used herein. The latter agrees with that given in the AGA, API, and CPA report of 1967 (p. 161). However, the principal difference lies in the amounts of gas estimated to be obtained from new fields still to be discovered, over and above the 825 trillion cubic feet estimated to be ultimately producible from fields already discovered. In the Potential Gas Committee's estimate, this would amount to 465 trillion cubic feet, which is just over twice the amount of our estimate of 218 trillion cubic feet, based on future oil discoveries.

At a gas-oil ratio of 7,500 ft^3/bbl, the new discoveries of crude oil that would have to accompany the future discovery of 465 trillion cubic feet of gas would amount to 62 billion barrels. The data in Figure 8.16 definitely do not support any such quantity but, rather, a figure of about half that amount.

Hence, although the estimate of the Potential Gas Committee of 1290 trillion cubic feet and that of 1044 trillion cubic feet based on a crude-oil analysis in conjunction with the gas-oil ratio are in substantial agreement, there still exists an excess of about 250 trillion cubic feet in the Potential Gas Committee's report which is difficult to reconcile with any likely amount of crude oil still to be discovered. If the 180 trillion cubic feet of gas classed as "speculative" by the Potential Gas Committee should be withdrawn, then a satisfactory agreement would be obtained.

Using the Potential Gas Committee's figure, Q_∞ = 1290 trillion cubic feet, the complete cycle of U.S. gas production is shown in Figure 8.20. According to this, a peak production rate of about 25 trillion cubic feet per year will occur about the year 1980. The time required to produce the middle 80 percent of the ultimate cumulative production will be the approximately 65-year period from about the years 1950 to 2015. Also shown is a curve of what the production would be until about 1985 if it were to continue the growth rate of 6.34 percent per year which has prevailed during recent decades.

A curve analogous to that in Figure 8.20 has also been computed for

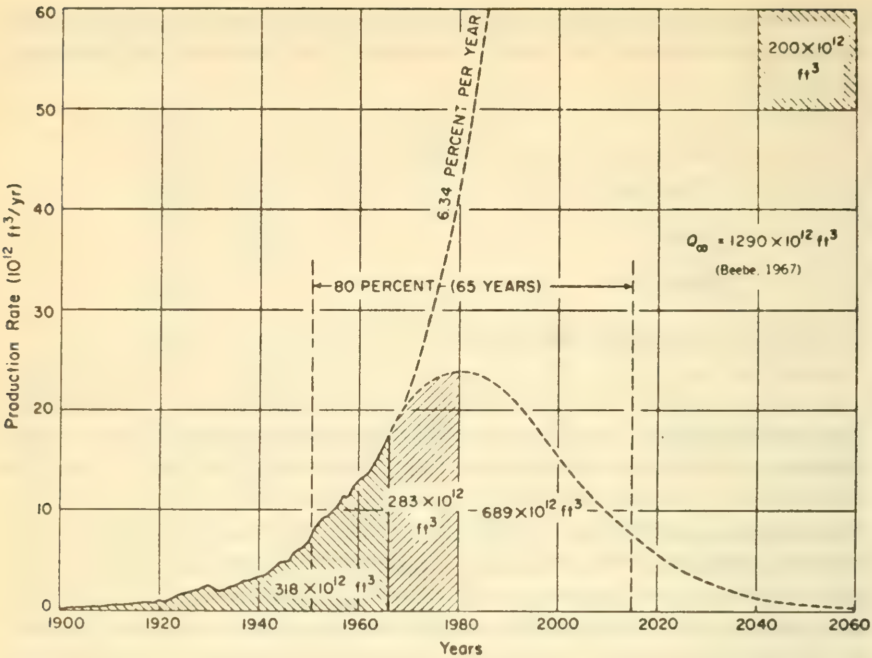

FIGURE 8.20
Complete cycle of natural-gas production in the United States and adjacent continental shelves, exclusive of Alaska.

Q_∞ = 1040 trillion cubic feet; it closely resembles the curve in Figure 8.20 except that the peak production rate is reduced to about 21 trillion cubic feet per year, and occurs at about the year 1978.

Estimates of Natural-Gas Liquids

The foregoing discrepancy in the estimates of future discoveries of natural gas carries over into estimates of natural-gas liquids. By 31 December 1966, the cumulative discoveries and proved reserves of natural-gas liquids for the conterminous United States were the following (API, AGA, and CPA, 1967, p. 116, 118, 207):

Cumulative production	9.86×10^9 bbls
Proved reserves	8.33×10^9 bbls
Cumulative discoveries	18.19×10^9 bbls

Since natural-gas liquids are produced along with natural gas, the signi-

ficant ratio for these two fluids is that of gas/NGL. If we take the cumulative discoveries of these two fluids from 1860 to 1967, this ratio is

$$\text{gas/NGL} = \frac{604 \times 10^{12}\ \text{ft}^3}{18.2 \times 10^9\ \text{bbls}}$$

$$= 33{,}200\ \text{ft}^3/\text{bbl}.$$

If, on the other hand, we take the corresponding ratio for the decades 1947 to 1957 and 1957 to 1967, we obtain:

For 1947-1957,

$$\text{gas/NGL} = 27{,}000\ \text{ft}^3/\text{bbl};$$

For 1957-1967,

$$\text{gas/NGL} = 26{,}000\ \text{ft}^3/\text{bbl}.$$

From these figures, it appears that the gas-NGL ratio is progressively decreasing with cumulative gas production. In view of this progressive decline in the gas-NGL ratio, it is difficult to justify a figure larger than 25,000 ft^3/bbl for future U.S. discoveries. Using this figure, in conjunction with cumulative proved discoveries of 604 trillion cubic feet by the beginning of 1967, and the two estimates of Q_∞ for natural gas, of 1044 trillion and 1290 trillion cubic feet, we obtain for the estimates of future discoveries of natural-gas liquids:

For $Q_\infty = 1044 \times 10^{12}\ \text{ft}^3$,

$$\text{NGL} = \frac{(1044 - 604) \times 10^{12}\ \text{ft}^3}{2.5 \times 10^4\ \text{ft}^3/\text{bbls}} = 17.6 \times 10^9\ \text{bbls};$$

For $Q_\infty = 1290 \times 10^{12}\ \text{ft}^3$,

$$\text{NGL} = \frac{(1290 - 604) \times 10^{12}\ \text{ft}^3}{2.5 \times 10^4\ \text{ft}^3/\text{bbl}} = 27.4 \times 10^9\ \text{bbls}.$$

When these figures are added to the 18.2×10^9 bbls of cumulative proved discoveries, we obtain 35.8 billion and 45.6 billion barrels for the estimated ultimate quantity of natural-gas liquids to be produced in the conterminous United States. On the basis of our previous comments concerning the natural-gas estimates, only the lesser of these two figures is compatible with our earlier analysis of crude oil, and is accordingly favored here. Using the smaller figure, rounded off to 36 billion barrels, the full cycle of U.S. production of natural-gas liquids is shown in Figure 8.21. According to the calculations on which this figure is based, a peak production

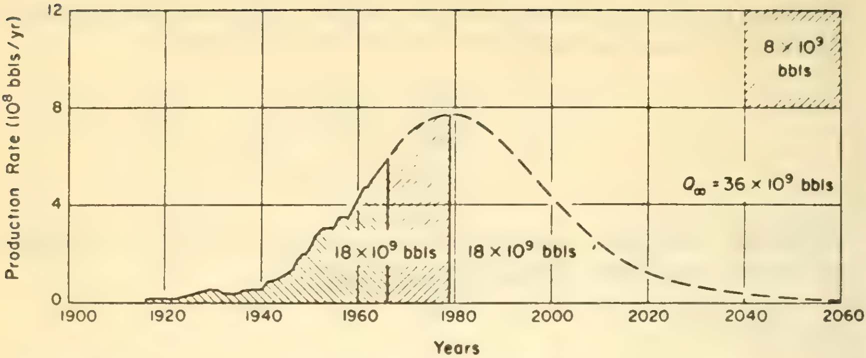

FIGURE 8.21
Complete cycle of production of natural-gas liquids in the United States and adjacent continental shelves, exclusive of Alaska.

rate of abcut 775 million barrels of natural-gas liquids per year will be reached at about 1980.

Total Petroleum Liquids

The sum of the production rate of crude oil and that of natural-gas liquids gives the production rate for petroleum liquids. Likewise, the sum of the ultimate amount of crude oil and of natural-gas liquids gives the ultimate amount of petroleum liquids to be produced. For the United States, exclusive of Alaska, this amounts to 165 billion barrels of crude oil plus 36 billion barrels for natural-gas liquids, or to 201 billion, rounded to 200 billion, barrels as the estimated magnitude of Q_∞ for petroleum liquids.

Using this value for Q_∞, the complete cycle of production of petroleum liquids is shown in Figure 8.22. A peak rate of production of about 3.5 billion barrels per year is estimated to occur during the first half of the 1970-decade, and production of the middle 80 percent of Q_∞ is expected to occur during the 64-year period from about the year 1937 to 2001. Also shown in Figure 8.22 is the course that the annual production would follow were it to continue at the constant rate of growth of 5.13 percent per year which prevailed from 1934 to 1952.

Estimates for Alaska. As stated above, the exploration for petroleum in Alaska is just in its beginning stages, and significant production of crude oil began only in 1958. Consequently, about the only guide for estimates at present is geological analogy coupled with the exploratory successes achieved thus far. On this basis a tentative allowance has already been made for an ultimate production of 25 billion barrels of crude oil. If we assume an average gas-oil ratio of 6,000 ft^3/bbl, which is about that for the rest of the

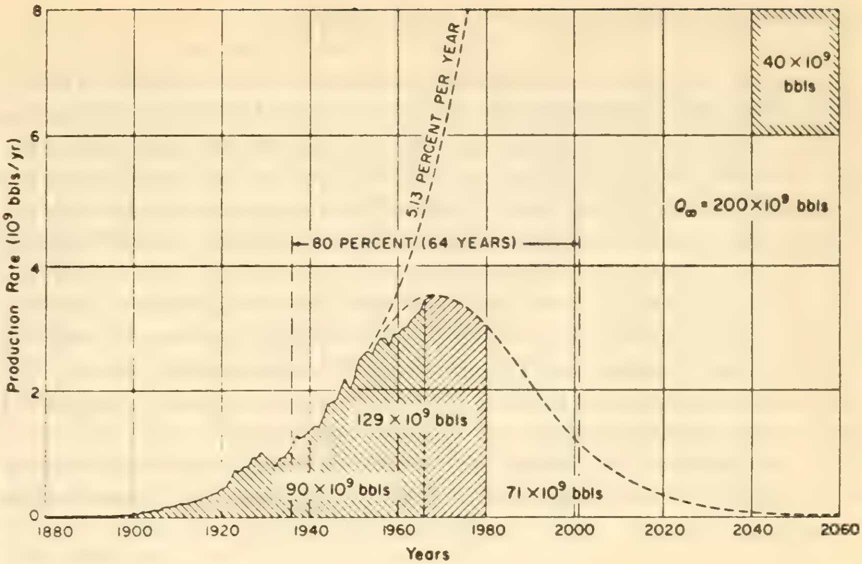

FIGURE 8.22
Complete cycle of production of petroleum liquids in the United States and adjacent continental shelves, exclusive of Alaska.

United States, this would give about 150 trillion cubic feet for the ultimate production of natural gas. And, at an average rate of 30,000 ft^3/bbl for the natural-gas—natural-gas liquids ratio, the estimated ultimate amount of natural-gas liquids would be about 5 billion barrels.

Total Petroleum for the Whole United States. These figures added to those already obtained for the rest of the United States give our present estimates for the ultimate amounts of petroleum fluids that the whole United States and its adjacent continental-shelf areas may reasonably be expected to produce. These estimates are given in Table 8.1.

TABLE 8.1
Estimated ultimate amounts of petroleum fluids to be produced by the United States (including contiguous continental shelves).

Region	Crude Oil (10^9 bbls)	Natural-gas Liquids (10^9 bbls)	Petroleum Liquids (10^9 bbls)	Natural Gas (10^{12} ft^3)
Conterminous United States	165	36	201	1,050
Alaska	25	5	30	150
Total	190	41	231	1,200

WORLD RESOURCES OF PETROLEUM

The Committee on Resources and Man is indebted to W. P. Ryman, Deputy Exploration Manager of Standard Oil Company of New Jersey, for several different world estimates of ultimate crude oil recovery, by major geographical areas (Table 8.2). Column one of Table 8.2 contains estimates made in January 1967 by *World Oil* of "proved" ultimately recoverable crude oil. Column two presents estimates of December 1966 made by *World Petroleum* of "proved and probable" ultimately recoverable crude oil. Finally, column three presents a 1962 estimate of L. G. Weeks, and column four a tentative estimate as of 1967 by W. P. Ryman of ultimately recoverable crude oil under normal expected recovery practices. The estimates of the last two columns each represent the sum of cumulative production plus proved reserves plus probable reserves plus future discoveries.

Our concern here is only with the estimates of Weeks and Ryman given in columns three and four, for these are the only ones that include future discoveries.

TABLE 8.2
Estimated ultimate recovery (EUR) of world crude oil, by geographical area (in billions of U.S. barrels).

	World Oil, Jan. 1967 Proved Reserves	*World Petr.,* Dec. 1966 Proved & Probable Reserves	L. G. Weeks, 1962 EUR[a]	W. P. Ryman, 1967 EUR[a]
Free World outside United States				
Europe	3.6	4.0	19	20
Africa	31.9	49.0	100	250
Middle East	273.7	304.1	780	600
Far East	15.1	17.1	85	200[b]
Latin America	56.9	64.4	221	225[b]
Canada	10.9	11.4	85	95
Total	392.1	450.0	1,290	1,390
United States	113.4	128.6	270	200
Total Free World	505.5	578.6	1,560	1,590
U.S.S.R., China, and satellites	65.5	86.7	440	500
Total World	571.0	665.3	2,000	2,090

Source: W. P. Ryman, Deputy Exploration Manager, Standard Oil Company of New Jersey.

[a] Based on normal expected recovery. Estimate includes: Produced + Proved + Probable + Future Discoveries.

[b] Includes offshore areas.

The Ryman estimates follow closely the earlier estimates of Weeks, but with some minor adjustments of the Weeks estimates for separate areas. With the exception of three cases, these adjustments to the Weeks estimates have been less than 11 percent. In the three exceptional cases, the Weeks estimate for Africa was increased from 100 billion to 250 billion barrels, that for the Far East from 85 billion to 200 billion barrels, and that for the United States was *decreased* from 270 billion to 200 billion barrels. For the world total, the Weeks estimate of 2,000 billion barrels was increased to 2,090 billion.

It is here considered that the Ryman estimates given in column four of Table 8.2 are about as accurate *relative* estimates of crude-oil resources of the various major regions of the world as can be made at the present time. The word "relative" is stressed, because the Ryman estimates follow closely those of Weeks. However, the Weeks estimates include a figure of 270 billion barrels for the United States, which is about 50 percent more than the highest figure that can be justified by the petroleum-industry data reviewed herein. Hence, if the Weeks method gives for the United States—the most completely explored region in the world (and its standard yardstick)—an estimate that is about 50 percent too large, it is a fair presumption that the same may be true of his estimate for the rest of the world also. In view of this possibility, two separate figures are here taken as the value of Q_∞ for the ultimate world production of crude oil: Ryman's estimate rounded off to 2,100 billion barrels, and a smaller figure of 1,350 billion barrels, which is about two-thirds of the Weeks estimate. It appears that the uncertainty of the world estimates at present is roughly within these limits.

The estimated full cycles of world crude-oil production, based on the two values, $Q_\infty = 2{,}100$ and $Q_\infty = 1{,}350$ billion barrels, are shown in Figure 8.23. For the smaller figure, a peak production rate of about 25 billion barrels per year is estimated to occur at about the year 1990, with the middle 80 percent of the cumulative production requiring only the 58-year period from 1961 to 2019. For the higher figure, the peak of the production rate of about 37 billion barrels per year would be delayed by only 10 years to about the year 2000. In this case, the time required to produce the middle 80 percent of the ultimate cumulative production would be increased to the 64-year period from about 1968 to 2032.

Mention should also be made of the recent world crude-oil estimates by Hendricks (1965). In these estimates, Hendricks used the same modification of the Zapp hypothesis that he used to obtain his estimate for the United States. Hendricks' estimate for the world crude oil eventually to be discovered is 6,200 billion barrels. This includes his estimate of 1,000 billion barrels for the United States. With an assumed 40-percent recovery factor, these two figures reduce to 2,480 billion and 400 billion barrels of recoverable crude oil for the world and the United States, respectively. Since his figure

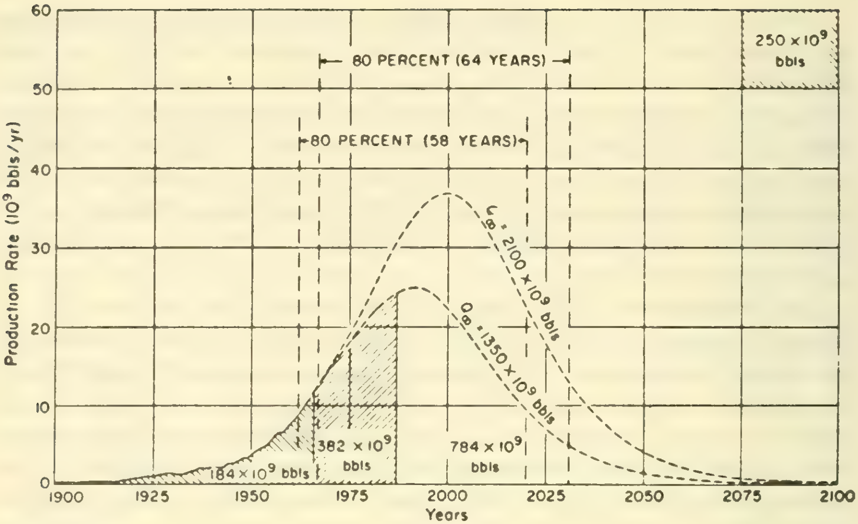

FIGURE 8.23
Complete cycles of world crude-oil production for two values of Q_∞.

of 400 billion barrels for the United States includes Alaska, it is to be compared with our present estimate of 190 billion barrels for the whole United States. Then, if a proportionate reduction is applied to the Hendricks world estimate, his figure of 2,480 billion barrels is reduced to 1,180, which is of the approximate magnitude of our lower figure of 1,350 billion barrels.

Another recent review of world petroleum resources was that given by D. C. Ion (1967) before the Seventh World Petroleum Congress in Mexico City, April 1967. This, however, was based so heavily upon the Hendricks estimate of 1965 that it can hardly be regarded as an independent estimate.

WORLD RESOURCES OF NATURAL GAS AND NATURAL-GAS LIQUIDS

As was true for U.S. production of natural gas during the earlier phases of the petroleum industry in the United States, the world production of natural gas has been handicapped in many areas by the absence of an accessible market. Consequently, much of the gas produced has been flared and wasted. However, recent advances in technology are eliminating much of this waste, so that eventually it is probable that most of the natural gas and natural-gas liquids produced will be conserved for industrial uses. Three main factors make this possible. One is an increase in gas-consuming industries, such as power production and the manufacture of Portland cement near centers of gas production. The second is the building of large-diameter pipelines for the transmission of gas from remote production

areas to main industrial centers of consumption. The third is the development of cryogenic tankers for transoceanic transportation of natural gas in a liquefied form.

To make a rough estimate of the world resources of natural gas and natural-gas liquids, about the best that can be done at present is to assume that the ratios of natural gas and of natural-gas liquids to crude oil for the whole world will be about the same as those for the United States, and that shortly most of these fluids will be utilized rather than wasted.

For the United States, the ratio of the estimated ultimate amount of natural gas to be produced to that of crude oil is about 6,400 ft^3/bbl; the corresponding ratio of natural-gas liquids to crude oil is about 0.22 bbls/bbl. For a rough estimate, these figures may be rounded off to 6,000 ft^3/bbl for the natural gas—crude-oil ratio and to 0.2 bbls/bbl for the natural-gas liquids—crude-oil ratio. Applying these ratios to our two previous estimates for the ultimate world crude-oil production gives corresponding estimates for the ultimate world production of natural gas and natural-gas liquids. These are given in Table 8.3. The estimates given by W. P. Ryman at the Vancouver conference for the ultimate world production of natural-gas liquids and natural gas were 375×10^9 bbls and $12{,}000 \times 10^{12}$ ft^3, respectively. Both of these figures are within the ranges indicated in Table 8.3.

TAR OR HEAVY-OIL SANDS

So-called tar, or heavy oil sands are impregnated with what is essentially a heavy crude oil that is too viscous to permit recovery by natural flowage into wells. Since such sands are as yet almost unexploited, no convenient world inventory of their occurrence is available. However, the best known of such deposits, and possibly the world's largest, are in the Province of Alberta, Canada. Pow, Fairbanks, and Zamora (1963) report on the large Athabasca deposit near Fort McMurray in northeastern Alberta and two

TABLE 8.3

Estimates of ultimate world production of natural-gas liquids, total petroleum liquids, and natural gas, based on two estimates of the ultimate production of crude oil.

Ultimate world crude-oil production (10^9 bbls)	Ultimate natural-gas liquids production (10^9 bbls)	Ultimate total petroleum liquids production (10^9 bbls)	Ultimate natural-gas production (10^{12} ft^3)
1,350	250	1,620	8,000
2,100	420	2,520	12,000

TABLE 8.4
Tar-sand deposits of Alberta, Canada.

Area	Evaluated Reserves (10^9 bbls)
Athabasca	266.9
Bluesky-Gething	20.6
Grand Rapids	13.3
Total	300.8

Source: Pow, Fairbanks, and Zamora (1963).

smaller groups: the Bluesky-Gething deposits in northwestern Alberta, and the Grand Rapids deposits in north-central Alberta.

Of these, the Athabasca deposit has an area of about 9,000 square miles and contains about 88 percent of the total evaluated tar-sand reserves of the Province. The Bluesky-Gething deposits have an area of about 1,800 square miles and contain about 7 percent of the evaluated reserves. The remaining deposits have an aggregate area of about 1,600 square miles and contain about 5 percent of the evaluated reserves. The thickness of overburden in the various deposits ranges from 0 at surface outcrops to about 2,000 feet.

The evaluated reserves of recoverable upgraded synthetic crude oil from the three groups of deposits are given in Table 8.4.

During the last half century, small-scale efforts to exploit these sands have repeatedly failed. Since 1966, however, the first large-scale mining and extraction plant, developed by a combination of major oil companies, has gone into successful operation. Development work has also been under way since 1958 by a number of other oil companies, who only await the approval of the provincial government to begin further exploitation.

If we compare the magnitude of the reserves of these deposits with that of the crude-oil resources of the United States, their potential importance in the comparatively near future, when domestic crude-oil production begins its decline, is immediately apparent. The oil from these sands has the additional advantage that, being in the same chemical family as crude oil, it can be processed by existing oil refineries without major modifications.

OIL SHALES

As remarked previously, oil shales differ from tar or heavy-oil sands in that their hydrocarbon contents are in a solid rather than a viscous-liquid form. Also shale oil differs considerably from crude oil in chemical content; it includes objectionable nitrogen and other impurities. Consequently, the oils from oil shales pose special problems in refining.

In the United States, the principal and best known oil-shale deposits are those of the Green River Formation in the Piceance Basin of northwestern Colorado, the Uinta Basin of eastern Utah, and the Green River Basin of southwestern Wyoming. Because the oil contents of these shales range from about 65 U.S. gallons per ton (1.5 barrels/ton) for the richest shales to near zero, some confusion exists in where to place the cutoff limit of oil content in estimating the magnitude of the resources. According to a study by Duncan and Swanson (1965, p. 13):

> Known oil-shale deposits that yield 10-25 gallons of oil per ton contain about 800 billion barrels oil equivalent in the Piceance Basin, Colo.; about 230 billion barrels in the Uinta Basin, Utah; and about 400 billion barrels in the combined Green River Basin and Washakie Basin, Wyoming.

These figures tend to be misleading unless tempered with the same authors' discussion elsewhere of "recoverable resources." These are said to be (ibid., p. 6):

> . . . (1) deposits yielding 25-100 gallons of oil per ton, in beds a few feet thick or more, extending to depths of 1,000 feet below surface and (2) some lower grade deposits yielding 10-25 gallons of oil per ton, in units 25 feet thick or more, which are minable by open-pit methods. About 50 percent of the oil shale in place is assumed to be minable under present conditions, although larger percentages could be recovered from parts of deposits minable by open-pit methods.

In view of these restrictions, the same authors list (their Table 2, p. 9) only 80 billion barrels as being "recoverable under present conditions" from the Green River Formation in Colorado, Utah, and Wyoming. Duncan and Swanson also list the carbonaceous Devonian and Mississippian shales of east-central United States, and other shale deposits, whose aggregate chemical energy contents are enormous, but the oil-equivalent content per ton is so small that they are classed as "marginal and submarginal."

The same authors have compiled a comprehensive summary of the known major deposits of carbonaceous shales throughout the world, and have given estimates of their oil contents in their Table 3 on page 18 (our Table 8.5). Again, it is significant that although the table gives a figure of about 2×10^{15} barrels as the order of magnitude of the total oil-equivalent content of these shales, only 190×10^{9}, or 190 billion barrels (including 80 billion for the U.S. Green River Shale), is listed as recoverable under present conditions.

Hence, the organic contents of the carbonaceous shales appear to be more promising as a resource of raw materials for the chemical industry than as a major source of industrial energy.

TABLE 8.5
Estimates of shale oil resources of world land areas (in billions of barrels).

Continents	Known Resources				Possible Extensions of Known Resources			Undiscovered and Unappraised Resources			Order of Magnitude of Total Resources[b]		
	Recoverable under Present Conditions	Marginal and Submarginal (oil equivalent in deposits)									Oil Equivalent in Deposits		
	Range in grade (oil yield, in gallons per ton of shale)												
	10–100	25–100	10–25	5–10	25–100	10–25	5–10	25–100	10–25	5–10	25–100	10–25	5–10
Africa	10	90	Small	Small	ne[a]	ne	ne	4,000	80,000	450,000	4,000	80,000	450,000
Asia	20	70	14	ne	2	3,700	ne	5,400	106,000	586,000	5,500	110,000	590,000
Australia and New Zealand	Small	Small	1	ne	ne	ne	ne	1,000	20,000	100,000	1,000	20,000	100,000
Europe	30	40	6	ne	100	200	ne	1,200	26,000	150,000	1,400	26,000	140,000
North America	80	520	1,600	2,200	900	2,500	4,000	1,500	45,000	254,000	3,000	50,000	260,000
South America	50	Small	750	ne	ne	3,200	4,000	2,000	36,000	206,000	2,000	40,000	210,000
Total	190	720	2,400	2,200	1,000	9,600	8,000	15,000	313,000	1,740,000	17,000	325,000	1,750,000

Source: Duncan and Swanson, 1965, Table 3, p. 18.
[a]ne = no estimate.
[b]Of the approximately 2×10^{15} bbls here indicated, 190×10^9 were considered recoverable under 1965 conditions.

RESOURCES OF COAL

World production of coal from 1860 to 1965 has already been shown in Figure 8.1, and that for the United States in Figure 8.4.

Unlike petroleum, coal occurs as stratified deposits in sedimentary basins. These commonly are continuous over wide areas and also frequently crop out at the surface of the ground. Consequently, by means of surface geological mapping, and a few widely spaced drill holes, it is possible to make reasonably accurate estimates of the coal resources of a given sedimentary basin in advance of mining, and to estimate the coal resources of the various sedimentary basins of the world. Then, with this knowledge, by means of the technique illustrated in Figure 8.8, it is possible to anticipate the period of time during which coal may be depended upon to supply a major part of the world's requirements for industrial energy.

The first world-wide inventory of coal, based on such considerations, was that reported to the Twelfth International Geological Congress at Toronto in the year 1913. Although many of the estimates at that time were very provisional, the estimate of minable coal resources for the entire world amounted to about 8×10^{12} metric tons. Since that time, geological mapping has been extended to all the land areas of the world. The result has been that large coal deposits in Siberia and China, which were little known in 1913, have been added to the estimates of that time, and estimates for other areas have been adjusted upward or downward as geological knowledge has increased.

During the last two decades, the U.S. Geological Survey has been engaged in a detailed study of the country's coal resources, and in connection with this study Paul Averitt has also made a succession of estimates of the coal resources of the world, using published national estimates of various countries, interpreted in conjunction with accruing geological information. In a report submitted to the Natural Resources Subcommittee of the Federal Council of Science and Technology, Averitt (1961) gave a table (Hubbert, 1962, p. 37) of the estimated remaining producible coal reserves of the world by principal regions and countries. Minable coal was taken to be 50 percent of the coal in the ground in seams 14 inches (0.36 meters) or more thick and less than 3,000 feet (900 meters) deep. Averitt's figure for the world was 2.3×10^{12} metric tons.

The foregoing figures pertain to coal deposits whose extent and magnitude are fairly accurately known from geological mapping and other data. Subsequently, Averitt has extended his studies to include not only the coal resources determined by mapping but also additional coal resources which, from geological information on the various coal-bearing areas, may

TABLE 8.6

Estimates of total original coal resources of the world by continents[a] (in billions of short tons).

Continent	Resources determined by mapping and exploration	Probable additional resources in unmapped and unexplored areas	Estimated total resources
Asia and European U.S.S.R.	7,000[b]	4,000	11,000[c]
North America	1,720	2,880	4,600
Europe	620	210	830
Africa	80	160	240
Oceania	60	70	130
South and Central Americas	20	10	30
Total	9,500[b]	7,330	16,830[c]

Source: Paul Averitt, 1969, Table 8, p. 82.

[a]Original resources in the ground in beds 12 inches thick or more and generally less than 4,000 feet below the surface, but includes small amounts between 4,000 and 6,000 feet.

[b]Includes about 6,500 billion short tons in the U.S.S.R.

[c]Includes about 9,500 billion short tons in the U.S.S.R. (Hodgkins, 1961, p. 6).

reasonably be inferred to exist. The results of these studies were presented to the Committee on Resources and Man during its meeting in Vancouver, 15–17 September 1967, and have since been published (Averitt, 1969) by the U.S. Geological Survey.

Averitt's current estimates, by continents, of the original coal in place are given in Table 8.6. In this case, the depth has been extended to 4,000 feet (1,200 meters), and in some cases to 6,000 feet (1,800 meters). Also the minimum thickness of seams considered has been reduced to 12 inches (0.3 meters). He pointed out, however, that the amount of coal added for the additional depth of 4,000–6,000 feet is small compared with that between 0 and 4,000 feet. In the United States, the coal in the 4,000–6,000-foot interval amounts only to about 10 percent of the total.

The data in Table 8.6 are expressed in short tons, and no breakdown by countries is given. However, in the footnote the Soviet Union is credited with $9{,}500 \times 10^9$ short tons, or $8{,}600 \times 10^9$ metric tons. In a separate detailed table, the original coal resources of the United States were given as $3{,}275 \times 10^9$ short tons, or $2{,}971 \times 10^9$ metric tons. From these data, the initial quantities of minable coal, taken as 50 percent of the coal present, have been computed by continents, and expressed in metric units, with separate estimates for the United States and the Soviet Union included. The results are shown graphically in Figure 8.24.

According to these estimates, about 65 percent of the world's initial coal resources were in Asia (including the European part of the Soviet

Union), about 27 percent in North America, less than 5 percent in Western Europe, and less than 3 percent in Africa, South and Central Americas, and Oceania (which includes Australia) combined. From these data, it is evident that the world's coal resources are not uniformly distributed.

World and United States production of coal and lignite have already been shown (Figures 8.1 and 8.4). Now, using Averitt's estimates of the ultimate amounts of minable coal for both the world and the United States, in conjunction with the principle that the area under the curves must not exceed those corresponding to the amounts of coal initially present, we can gain a reasonably reliable impression of the future possibilities in coal production. For world production, this is shown in Figure 8.25, using for the ultimate cumulative production Q_∞, Averitt's estimate of 7.6×10^{12} metric tons, and also a smaller figure of 4.3×10^{12}, which is approximately the amount of coal established by mapping.

For the larger value for Q_∞ of 7.6×10^{12} metric tons, should the annual production rate double only three more times to a maximum rate of eight times that of the present, the date of this peak rate would occur about 170 to 200 years hence. Should the maximum rate be higher than this, the peak date would occur sooner; should it be lower, later. For the smaller value for Q_∞ of 4.3×10^{12} metric tons, the curve is drawn for a sixfold increase in the production rate over that of the present. In this case, the peak rate would occur somewhat earlier, or about 140 years hence.

Corresponding graphs of future coal production in the United States are shown in Figure 8.26 for two values of Q_∞. The larger figure of $1{,}486 \times 10^9$

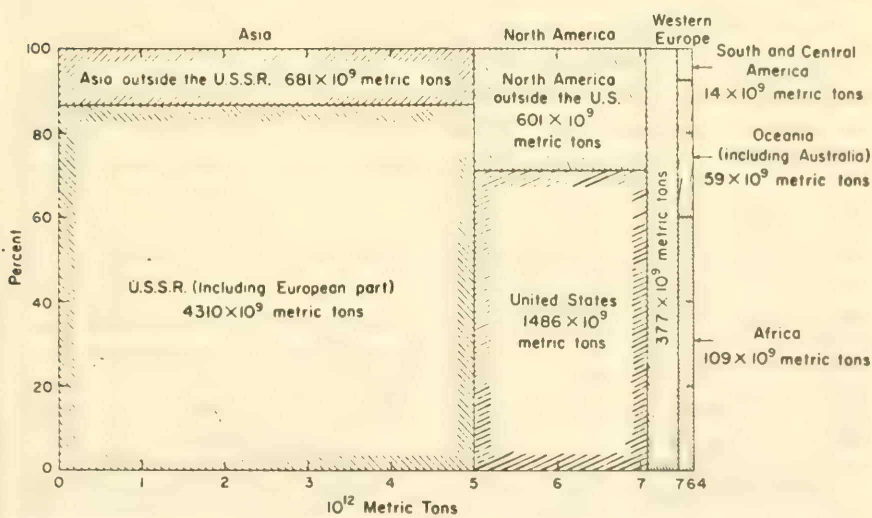

FIGURE 8.24
Estimates of world resources of minable coal and lignite. (Data from Averitt, 1969.)

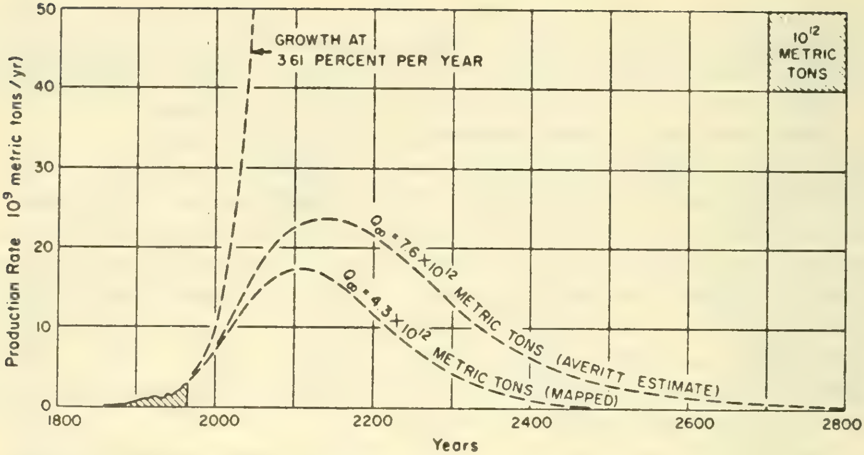

FIGURE 8.25
Complete cycles of world coal production for two values of Q_∞.

metric tons represents minable coal based on Averitt's recent estimate of the initial U.S. coal resources. The smaller figure of 740×10^9 metric tons is approximately the amount of coal determined by mapping. For the higher-rate curve, the assumed maximum production rate represents an eightfold increase over the present rate, or three future doublings. The smaller-rate curve assumes a fivefold increase in the rate of production. The peak production rates for these two curves would occur at about the years 2220 and 2170, respectively.

As was true for petroleum, the significant question about coal is not how

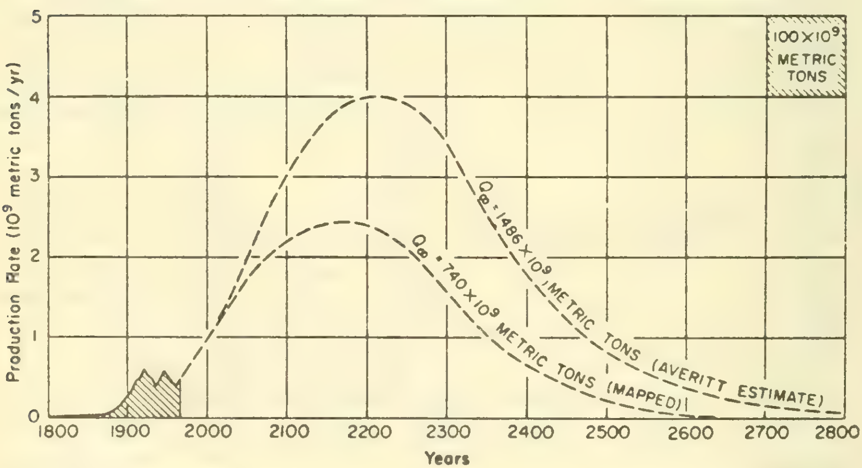

FIGURE 8.26
Complete cycles of United States coal production for two values of Q_∞.

long it will last, but rather, over what period of time can it serve as a major source of industrial energy? In answer to this, we may eliminate the long periods of time at relatively low rates of production required to produce the first and last 10-percentiles of the ultimate cumulative production Q_r, and consider only the time span required to consume the middle 80 percent. For the world, using the higher value for Q_r of 7.6×10^{12} metric tons, the time required for the middle 80 percent, as determined from Figure 8.25, would be approximately the 340-year period from the year 2040 to 2380. For the United States, using the larger figure for Q_r of about 1.49×10^{12} metric tons, the time required to consume the middle 80 percent, as determined from Figure 8.26, would be approximately the 400-year period from about the year 2040 to 2440.

These figures, of course, are only approximate, but they do indicate the expectable order of magnitude of the length of time during which coal could serve as a major source of energy for the nation and the world. In both cases, should the smaller values of Q_x shown by the lower curves in Figures 8.25 and 8.26 be used, or should the peak rates of production be higher than those shown, the time would be correspondingly shortened.

CONCLUSIONS CONCERNING THE FOSSIL FUELS

For the purpose of the present study, the principal result of the foregoing estimates of the approximate magnitudes of both the United States' and the world's supply of the fossil fuels are the following:

If these substances continue to be used principally for their energy contents, and if they continue to supply the bulk of the world's energy requirements, the time required to exhaust the middle 80 percent of the ultimate resources of the members of the petroleum family—crude oil, natural gas, and natural-gas liquids, tar-sand oil, and shale oil—will probably be only about a century.

Under similar conditions, the time required to exhaust the middle 80 percent of the world's coal resources would be about 300 to 400 years (but only 100 to 200 years if coal is used as the main energy source).

To appreciate the bearing of these conclusions on the long-range outlook for human institutions, the historical epoch of the exploitation of the world's supply of fossil fuels is shown graphically in Figure 8.27, where the rate of production of the fossil fuels as a function of time is plotted on a time scale extending from 5,000 years ago to 5,000 years in the future—a period well within the prospective span of human history. On such a time scale, it is seen that the epoch of the fossil fuels can only be a transitory and ephemeral event—an event, nonetheless, which has exercised the most drastic influence experienced by the human species during its entire biological history.

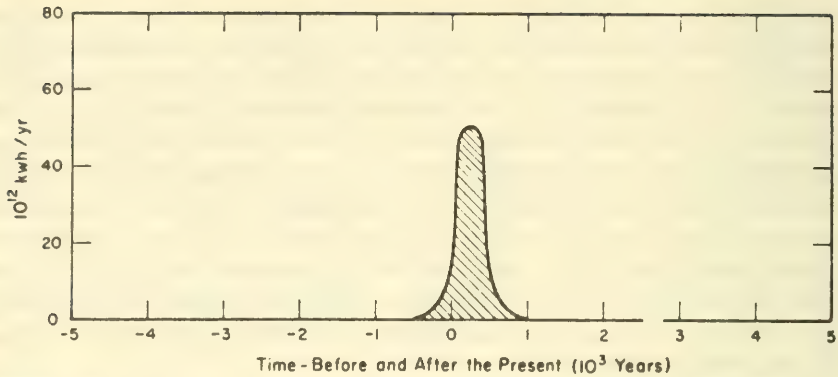

FIGURE 8.27
Epoch of exploitation of fossil fuels in historical perspective from minus to plus 5,000 years from present. (From Hubbert, 1962, Figure 54, p. 91.)

OTHER SOURCES OF ENERGY

In view of the exhaustibility and comparatively short time span for the duration of the fossil fuels, if the world's state of industrialization is to survive the decline of fossil fuels, other sources of energy and power of comparable magnitude must be found. Possible sources will now be reviewed with this requirement in mind.

Solar Energy

The first and most obvious of possible large energy sources is solar radiation, which is extensively discussed by Farrington Daniels (1964) in his excellent book, *Direct Use of the Sun's Energy*. In magnitude, the thermal solar power per square centimeter at the mean distance of the earth from the sun amounts, outside the earth's atmosphere, to 0.139 watts/cm^2, and the thermal power intercepted by the earth's diametral plane is 17.7×10^{16} watts, which is about a hundred-thousand times larger than the world's present installed electric-power capacity. Hence, solar power is of adequate magnitude. It also has the virtue of remaining nearly constant over time periods of millions of years—much longer than the probable duration of the human species. Solar radiation is also the energy source, through the mechanism of photosynthesis, for the entire biological system.

As Daniels discusses in detail, many practical nonbiological uses can be made of solar energy on a small scale. These include such uses as water and house heating, air conditioning, distillation, solar furnaces, solar cookery, and numerous thermoelectric, photoelectric, and other means of electrical conversion or storage of solar energy. However, our principal concern at

present is with the question of whether it is likely that our requirements for large-scale electrical power, now supplied by the fossil fuels and water power, could be met by means of solar power. In particular, since modern power stations fall largely in the range of 100 to 1,000 megawatts each, what is the likelihood of building solar power plants of such magnitudes?

Consider, in particular, a solar-electric power plant of 1,000 electric megawatts capacity. With a conversion factor from solar power to electrical power of 10 percent, such a plant would require a solar power input of 10,000 megawatts, or 10^{10} thermal watts. According to Daniels (1964, Table 1, p. 22), the average solar power at the earth's surface amounts to about 500 cal/cm^2/day. This, when averaged over a full day, gives an average solar power input of about 2.4×10^{-2} watts/cm^2. Then, the area of the earth's surface required to collect 10^{10} watts of solar power would be

$$10^{10}\ \text{watts}/(2.4 \times 10^{-2}\ \text{watts/cm}^2) = 42 \times 10^{10}\ \text{cm}^2,$$

which would be 42 km^2, or a square area of 6.5 km per side.

There is no question that it is physically possible to cover such an area with energy-collecting devices, and to transmit, store, and ultimately transform the energy so collected into conventional electric power. However, the complexity of such a process, and its cost in terms of the metals and physical, chemical, and electrical equipment required, in comparison with the requirements for present thermoelectric or hydroelectric equipment of the same capacity, renders such an undertaking to be of questionable practicability.

At present, therefore, the principal uses of solar energy, in addition to the natural processes of photosynthesis and the maintenance of the atmospheric, hydrologic, and oceanic circulations, appear to be small-scale, special-purpose uses.

Water Power

Water power represents the largest concentration of solar power that is produced by any natural process, and five hydroelectric plants already exist in the United States with power capacities exceeding 1,000 megawatts each. The history of the use of water power dates from Roman times, and, in the United States, water power has been extensively employed for the driving of grist mills, saw mills, textile mills, and other manufacturing establishments during the eighteenth and nineteenth centuries. However, because of the difficulties inherent in power transmission by mechanical devices, such plants rarely exceeded a few hundred kilowatts in power capacity.

It was not until the development of electrical-power transmission at about the beginning of the present century that large-scale generation and trans-

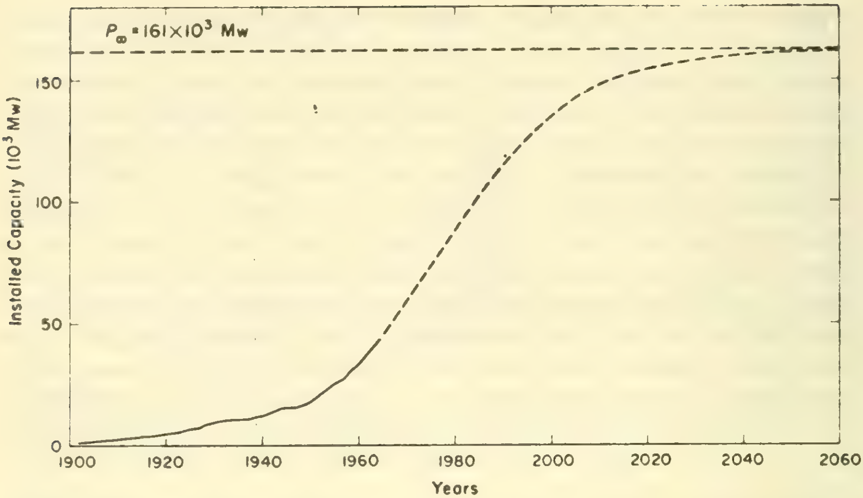

FIGURE 8.28
United States installed and potential water-power capacity.

mission of water power became possible. Since that time, the installation of hydroelectric power capacity in the United States has followed the customary growth curve shown in Figure 8.28. Installed capacity at present amounts to about 45,000 megawatts. As to the future, there is a fairly definitely determined ultimate maximum power capacity, P_∞, which for the United States is given by the Federal Power Commission to be about 161,000 megawatts. This is determined from the stream-flow records for the whole country which have been recorded for many years by the U.S. Geological Survey.

The Geological Survey has also made estimates from time to time of the potential water-power capacities of the various continents for the world as a whole.

Table 8.7, prepared from a summary by Francis L. Adams (Hubbert, 1962, p. 99), of the Federal Power Commission, utilizing basic U.S. Geological Survey data, gives the potential water-power capacities of the world by principal regions. The total world capacity is given as 2,857,000 megawatts. Of this, it is significant that the continents of Africa and South America, both of which are deficient in coal, have the highest potential water-power capacities of all the continents—780,000 megawatts for Africa and 577,000 for South America.

By 1964, the installed water-power capacity of the world amounted to 210,000 megawatts (U.S. Federal Power Commission, 1966, Table 5, p. 7), which is only about 7.5 percent of its potential capacity. The total installed electrical-power capacity of the world amounted at the same time to 734,000 megawatts. Hence, the total potential water-power capacity of the world is still about four times as large as total installed electric-power capacity.

It thus appears that if the world's potential conventional water-power capacity were fully developed it would be of a magnitude comparable to the world's total present rate of energy consumption. From this, it might be inferred that without the present supply of fossil fuels, the world could continue at an industrial level comparable to that of the present on water-power alone. Offsetting such an expectation are two contrary considerations. The first is the aesthetic one of whether the people of the world wish to sacrifice some of their most beautiful natural scenery in order to develop fully the associated water power. The second concerns the fact that in all reservoirs formed by dammed streams, the streams are continuously depositing their loads of sediments, so that in periods of a century or two most man-made reservoirs are due to become completely filled by such sediments. This problem has not been satisfactorily solved, and may never be. Hence, although the stream rates of discharge may remain relatively stable for millenia, most water-power sites may have periods of maximum usefulness measured by a century or two. It is accordingly questionable to what extent the world may be able to depend upon water power as a substitute for the depleted fossil fuels.

Tidal Power

Another source of power having a longevity measurable in geologic time is tidal power. Tidal power is similar in all essential respects to hydroelectric power except that, whereas hydroelectric power is obtained from the energy of unidirectional streamflow, tidal-electric power is obtained from

TABLE 8.7
World water-power capacity.

Region	Potential (10^3 Mw)	Percent of total	Development (10^3 Mw)	Percent developed
North America	313	11	59	19
South America	577	20	5	
Western Europe	158	6	47	30
Africa	780	27	2	
Middle East	21	1	—	
Southeast Asia	455	16	2	
Far East	42	1	19	
Australasia	45	2	2	
U.S.S.R., China and satellites	466	16	16	3
Total	2,857	100	152	

Source: M. King Hubbert, 1962, Table 8, p. 99, computed from data summarized by Francis L. Adams, 1961.

the oscillatory flow of water in the filling and emptying of partially enclosed coastal basins during the semi-diurnal rise and fall of the oceanic tides. This energy may be partially converted into tidal-electric power by enclosing such basins with dams to create a difference in water level between the ocean and the basin, and then using the waterflow while the basin is filling or emptying to drive hydraulic turbines propelling electric generators.

In order to obtain a quantitative evaluation of the amount of tidal energy potentially obtainable from a given basin, it is useful to determine the maximum amount of energy that can be dissipated into heat during one complete tidal cycle. This is the amount of energy that would be dissipated if the dam gates were closed at low tide when the water in the basin is at its lowest level, and then opened wide allowing the basin to fill at the crest of the tide; and, in a similar manner, by closing the gates when the basin is filled at high tide, and then allowing the basin to empty at low tide.

This maximum possible amount of energy dissipated during one tidal cycle is given by

$$E_{\max} = \rho g R^2 S, \tag{7}$$

where ρ is the density of sea water, g the acceleration of gravity, R the tidal range, and S the surface area of the basin. When all of the quantities to the right in equation (7) are in meter-kilogram-second units, the energy will be in joules.

The maximum possible average power obtainable from such a basin would be obtained if all of the energy $E_{\max}$ in equation (7) were converted into electrical energy. This maximum average power would then be given by

$$\bar{P} = \frac{E_{\max}}{T} = \frac{\rho g R^2 S}{T}, \tag{8}$$

where T is the half period of the synodical lunar day. This is 12 hours and 24.4 minutes, or 4.46×10^4 seconds. When T is in seconds, $\bar{P}$ will be expressed in joules/second, or watts.

The actual energy and power obtainable by means of turbines and electrical generators from such a basin can be only a fraction of the quantities given in equations (7) and (8). In engineering design computations for various tidal-power projects, the amounts of energy and power producible are commonly within the range of 8–20 percent of these maximum amounts, although in one instance, that of la Rance in France, the realizable power approaches 25 percent.

The source of tidal energy is the combined kinetic and potential energy of the earth-moon-sun system. Hence, as this energy is dissipated on the earth, equivalent changes must occur in the rotational energy of the earth, and in the orbital motions of the moon about the earth and of the earth about the sun. These motional changes, which have been observed astro-

nomically over a period of about three centuries, indicate that the day is lengthening by about 0.001 second per century with a corresponding decrease in the earth's rotational velocity. From such astronomical data, Munk and MacDonald (1960, p. 219) have recently estimated that the rate of tidal dissipation of energy on the earth is about 3×10^{12} watts.

A considerable fraction of this dissipation occurs in the oceans, especially in the shallow seas, bays, and estuaries, where the tidal ranges and tidal currents, because of inertial effects, become much greater than those in the open oceans. The oceanic tides, as measured on islands in the open oceans, have ranges commonly of less than a meter, whereas those in bays and estuaries have ranges, as shown in Table 8.8, from 1 to more than 10 meters.

A method of estimating the amount of energy dissipated by tides in shallow seas was developed in 1919 by G. I. Taylor and applied to the Irish Sea. The following year, this method was extended by Harold Jeffreys (1920; 1959, p. 241–245) to most of the shallow seas of the earth for which he estimated a rate of energy dissipation at spring tides of about 22×10^{11} watts, of which 15×10^{11} watts, or two-thirds of the total was accounted for by the Bering Sea alone.

Recently, using oceanographic data subsequently acquired, Munk and MacDonald (1960, p. 209–221) have re-estimated the energy dissipation in shallow seas. They obtained an average rate of, at most, 10^{12} watts, which is slightly less than the 1.1×10^{12} watts obtained when Jeffrey's rate for spring tides is reduced by a factor of 0.5 to give an average rate. Munk and MacDonald obtained a drastic reduction of Jeffrey's estimate for the Bering Sea from 75×10^{10} ($\frac{1}{2}$ of 15×10^{11}) to only 2.4×10^{10} watts.

The significance of these estimates is that they establish a limit to the maximum amount of power that could possibly be developed from tidal sources. In Table 8.8, which is based on data compiled by Trenholm (1961) and by Bernshtein (1965), a summary is given of the average tidal ranges and basin areas for most of the more promising tidal-energy localities of the world. In addition, the average potential power, and maximum energy dissipation per year, as computed from equations (7) and (8), are given for each locality. The total maximum rate of energy dissipation for these localities amounts to 6.4×10^{10} watts, or 64,000 megawatts. This is about 6 percent of the Munk and MacDonald estimate of a dissipation rate of 10^{12} watts for all of the shallow seas. If we make a liberal allowance of 20 percent for the actual average power recoverable at each of these sites, we obtain a result of about 13×10^{9} watts, or 13,000 megawatts as the approximate magnitude of the average value of the world's potential tidal-electric power. Comparing this with the estimate of the world's potential water power of about 2,900,000 megawatts given in Table 8.7, it will be seen that the world's potential tidal power amounts to less than 1 percent of its potential water power.

TABLE 8.8
Tidal power sites and maximum potential power.

Location	Average range R (meters)	R^2 (m^2)	Basin area S (km^2)	R^2S (m^2)(km^2)	Average potential power P (10^3 kw)	Potential annual energy E (10^6 kwh)
North America						
Bay of Fundy						
Passamaquoddy	5.52	30.5	262	7,990	1,800	15,800
Cobscook	5.5	30.3	106	3,210	722	6,330
Annapolis	6.4	41.0	83	3,440	765	6,710
Minas-Cobequid	10.7	114	777	88,600	19,900	175,000
Amherst Point	10.7	114	10	1,140	256	2,250
Shepody	9.8	96	117	11,200	2,520	22,100
Cumberland	10.1	102	73	7,450	1,680	14,700
Petitcodiac	10.7	114	31	3,530	794	6,960
Memramcook	10.7	114	23	2,620	590	5,170
Subtotal					29,027	255,020
South America						
Argentina						
San José	5.9	34.8	750	26,100	5,870	51,500
Europe						
England						
Severn	9.8	96.0	70	7,460	1,680	14,700

France						
Aber-Benoît	5.2	27.0	2.9	78	18	158
Aber-Wrac'h	5.0	25.0	1.1	28	6	53
Arguenon & Lancieux	8.4	70.6	28.0	1,980	446	3,910
Frênaye	7.4	54.8	12.0	658	148	1,300
La Rance	8.4	70.6	22.0	1,550	349	3,060
Rothéneuf	8.0	64.0	1.1	70	16	140
Mont Saint-Michel	8.4	70.6	610	43,100	9,700	85,100
Somme	6.5	42.3	49	2,070	466	4,090
Subtotal					11,149	97,811
U.S.S.R.						
Kislaya Inlet	2.37	5.62	2.0	11	2	22
Lumbovskii Bay	4.20	17.6	70	1,230	277	2,430
White Sea	5.65	31.9	2,000	63,800	14,400	126,000
Mezen Estuary	6.60	43.6	140	6,100	1,370	12,000
Subtotal					16,049	140,452
Grand Total					63,775	559,483

Sources: N. W. Trenholm, 1961; L. B. Bernshtein, 1965 (1961), Table 5-5, p. 173.

Although small tidal mills for the grinding of grain and similar purposes have been used since about the twelfth century, it is only within recent decades that tidal-electric installations have been given serious engineering consideration, and only within the last three years actually brought into operation.

One of the best known of such projects has been that of Passamaquoddy Bay on the United States-Canadian boundary off the Bay of Fundy. This bay has an area of 262 km^2 and an average tidal range of 5.52 meters, with a maximum potential average power (Table 8.8) of 1,800 megawatts. Plans were drafted for such a project during the early 1930's and construction was actually started before the project was finally killed by lack of Congressional appropriation. In 1948, interest in a Passamaquoddy Tidal Power Project was revived and a new engineering study was authorized by the United States and Canadian governments. This involved the establishment of an International Joint Commission and The International Passamaquoddy Engineering Board to study and draw engineering plans for such a project.

The Engineering Board, in its report of 1959, recommended a two-pool project involving both Passamaquoddy and Cobscook Bays, but with the power obtained solely from Passamaquoddy Bay during its emptying phase. This would have a power plant consisting of 30 unidirectional turbogenerator units of 10,000 kw capacity each, or a total installed capacity of 300,000 kw, with an annual energy production of $1{,}843 \times 10^6$ kwh. Comparing the latter figure with that of $15{,}800 \times 10^6$ kwh given in Table 8.8 as the maximum energy obtainable annually indicates that the proposed system would utilize but 11.8 percent of the energy potentially available.

After studying this report, the International Joint Commission concluded that the project would be economically infeasible. In response, President John F. Kennedy, by letter of 20 May, 1961, requested the Department of the Interior to restudy the project and propose modifications. This resulted in a recommendation (Udall, 1963) that the power capacity be increased from 300,000 to 1 million kw in order to deliver most of the power during the brief period of peak demand. It also involved a slight reduction from $1{,}843 \times 10^6$ to $1{,}318 \times 10^6$ kwh in the annual energy production.

This was recommended to the President for authorization, but as yet no authorization has been obtained.

For the installation of the world's first major tidal-electric plant, that of la Rance estuary which began operation in 1966 (*Engineering*, July 1966, pp. 17–24), honor is due to France. Here, the average tidal range is 8.4 meters, and the power plant is in a dam enclosing an area of 22 km^2. The power plant comprises 24 units of 10,000 kw capacity each, and the annual production of energy was estimated to be 544×10^6 kwh, which amounts to about 18 percent of the total energy available (Table 8.8). If the capacity is increased, as planned, to 320,000 kw, this would increase the power utilization

to about 24 percent of that potentially obtainable. This high figure has been made possible by the use of turbines of an advanced design. These are horizontal, axial-flow turbines with adjustable blades permitting operation during both the filling and the emptying of the basin, and also their use as pumps.

The most recent tidal-electric project to go into operation, as reported by *The New York Times* on 30 December 1968, is a small Russian experimental station in the Kislaya Inlet on the Coast of the Barents Sea, 80 kilometers northwest of Murmansk. This consists of a single unit driven by a 400-kilowatt turbine of French manufacture. A second unit is to be installed later, bringing the total power capacity to 800 kw.

According to the same article, a much larger 320,000-kilowatt plant is planned for the Lombovska River (Lumbovskii Bay, Table 8.8) on the northeast coast of the Kola Peninsula, and a 14-million-kilowatt plant for the Mezen Bay on the east side of the mouth of the White Sea. Since the stated capacities of these two plants are both larger than the maximum potential average power obtained from the Bernshtein data in Table 8.8, either the figures are exaggerated, or else it is now planned to enclose larger basins than those given by Bernshtein (1965, Table 5-5, p. 173).

In summary, it may be said that although the world's potential tidal power, if fully developed, would amount only to the order of 1 percent of its potential water power, and to an even smaller fraction of the world's power needs, it nevertheless is capable in favorable localities of being developed in very large units. It has the additional advantage of producing no noxious wastes, of consuming no exhaustible energy resources, and of producing a minimum disturbance to the ecologic and scenic environment. There are accordingly many social advantages and few disadvantages to the utilization of tidal power wherever tidal and topographical factors combine to make this practicable.

Geothermal Energy

One of the energy inputs into the earth's surface environment consists of the heat conducted from the earth's interior as a result of the increasing temperature with depth; another consists of the heat convected to the surface by volcanoes and hot springs. In special geological situations in volcanic areas, underground water is trapped in porous or fractured rocks and becomes superheated from volcanic heat. Wells drilled into such reservoirs of superheated water or steam permit the steam to be conducted to the surface where it can be used as an energy source for a conventional steam-electric power plant.

It is only within recent decades that large geothermal-electric power plants have been built (Table 8.9). The earliest utilization of geothermal

TABLE 8.9
Developed and planned geothermal-electric power installations.

Country and locality	Installed capacity 1969 (megawatts)	Planned additional capacity (megawatts)	Total capacity by early 1970's (megawatts)	Date of earliest installation
Italy[a]				
Larderello	370		370	1904
Monte Amiata	19		19	ca 1962
Total	389		389	
United States[b]				
The Geysers, California	82	100	182	1960
New Zealand[b]				
Wairakei	290		290	Nov. 1958
Mexico[b]				
Pathé	3.5		3.5	ca 1958
Cerro Prieto (Mexicali)		75	75	ca 1971
Total	3.5	75	78.5	
Japan[b,c]				
Matsukawa	20	40	60	Oct. 1966
Otake	13	47	60	Aug. 1967
Goshogate		10	10	
Total	33	97	130	
Iceland[d]				
Hveragerdi	(Geothermal energy for house and greenhouse heating)	17	17	1960
U.S.S.R.[e]				
Kamchatka				
Pauzhetsk	5	7.5	12.5	1966
Paratunka	0.75		0.75	1968
Bolshiye Bannyye	25		25	1968
Total	30.75	7.5	38.25	
Grand Total	828.25	296.5	1,124.75	

Sources: [a]Facca and Ten Dam, 1964. [b]Donald E. White, U.S. Geological Survey, June 1969, personal communication. [c]Julian W. Feiss, 1968, personal communication. [d]Icelandic Embassy, Washington, D.C., July 1969. [e]Donald C. Alverson, Foreign Geology Branch, U.S. Geological Survey, July 1969, personal communication.

energy for power was at Larderello, in the Tuscany province of Italy, in 1904. The capacity of power plants in this locality has been increased to about 370 megawatts as of 1969. Recently two new thermal fields in the Monte Amiata region about 70 kilometers southeast of Larderello have been discovered, and smaller power plants installed. The Bagnore field has two generators of 7 Mw each, and the Piancastagnaio field, one station of 5 Mw. This gives a total geothermal power capacity for Italy of just under 400 Mw.

After Italy, the largest development of geothermal power is at Wairakei,

New Zealand. There, drilling for steam was begun about 1950 and the first power plant began operation in November 1958. The plant has been expanded to a capacity of 290 Mw in 1969.

The third largest project is in the United States at The Geysers in northern California. Here, power production began in 1960 with a 12.5 Mw unit. The plant capacity has been expanded to 82 Mw and an additional capacity of 100 Mw is planned for the near future.

In Japan, geothermal-power production was begun at Matsukawa in 1966 and at Otake in 1967. The total 1969 capacity of these two plants is 20 Mw and 13 Mw, respectively, with planned increases to 60 Mw each. These, plus a planned 10 Mw plant at Goshogate, will give Japan a total capacity of 130 Mw by the early 1970's.

Mexico now operates a small pilot plant of 3.5 Mw capacity at Pathé, about 200 kilometers north of Mexico City. A much larger thermal field has been drilled at Cerro Prieto, in Baja California, about 25 kilometers southeast of Mexicali on an extension of the San Andreas fault system. Two of the wells in this field are said to have the largest steam production of any in the world. Two power units of 37.5 Mw each are due to begin operation in 1970 or 1971.

Iceland has large geothermal fields. The steam from one of these is used for space heating of almost the entire town of Hveragerdi, and for large greenhouses nearby. No geothermal-electric power is yet produced (1 July 1969), but a plant of 17 Mw capacity at Hveragerdi is expected to begin operation before the end of 1969.

In the Soviet Union, the only geothermal power produced is at three small plants in Kamchatka (Pauzhetsk, Paratunka, and Bolshiye Bannyye) with a total present capacity of 30.75 Mw and a planned increase to 38.25 Mw.

The relevant data are summarized in Table 8.9, according to which the present installed geothermal-electric power capacity of the world amounts to 828 Mw with planned increases to 1,125 Mw by 1971–72. With regard to the ultimate world capacity of geothermal power, only an order-of-magnitude figure can be given. Basic information on geothermal installations and estimated potential power capacities of various countries is summarized by Baldwin and McNair (1967). By far the most comprehensive compilation on thermal springs, however, is that by Waring, Blankenship, and Bentall (1965), who give basic geologic data on flow rates and temperatures but do not interpret the data in terms of potential geothermal power.

A better appraisal of the quality of energy involved is given by Donald E. White (1965). For most of the better-known geothermal areas of the world, White has estimated the rate at which heat is discharged to the surface of the earth, and has also estimated the amount of stored heat above surface temperatures to depths of 3 kilometers and 10 kilometers. From the areas studied, he estimates that the world's total natural heat flow from all hydro-

thermal areas is of the order of 3×10^{10} cal/sec, or about 1.3×10^{11} thermal watts. He also estimates that the total stored heat of all hydrothermal systems to a depth of 3 kilometers amounts to 2×10^{21} cal (8×10^{21} thermal joules), while to a depth of 10 kilometers it amounts to 1×10^{22} cal (4×10^{22} thermal joules). Of the world's hydrothermal energy, White estimates that about 5–10 percent occurs in the United States, mainly in the western states.

To obtain an order of magnitude for geothermal power, White assumes that about 1 percent of the hydrothermal energy can be converted into electrical energy. For the depth of 10 kilometers, 1 percent of the estimated thermal energy would be 1×10^{20} cal, or 4×10^{20} thermal joules. For a 0.25 conversion factor, this would represent 1×10^{20} joules of electrical energy, or about 3×10^6 Mw-yrs. Then, if this amount of energy were to be withdrawn during a period of 50 years, the average annual geothermal-electric power would be

$$\frac{3 \times 10^6 \text{ Mw-yrs}}{50 \text{ years}} = 60{,}000 \text{ Mw},$$

or about 60 times the present installed capacity. This agrees with White's conclusion that the world's geothermal energy resources could sustain a rate of withdrawal of 10–100 times that of the present for at least the next 50 years.

It thus appears that the ultimate magnitude of geothermal power production will probably be in the tens of thousands of megawatts. While this is a significant amount of power, a better idea of just how significant can be obtained by comparison with other sources of power. A figure of 60,000 Mw for geothermal power is about the same as that of 64,000 Mw given in Table 8.8 for the world's potential tidal power, but only 2 percent of the 2.8×10^6 Mw given in Table 8.8 for the world's potential water power from conventional sources. It is only about a third larger than the present hydroelectric power capacity, or only about 20 percent of the present total installed electric power capacity of the United States. Hence, while geothermal energy is capable of sustaining a large number of small power plants in a limited number of localities, it still represents only a small fraction of the world's total energy requirements, and this for only a limited period of time.

NUCLEAR ENERGY

For a final source of energy appropriate for large-scale generation of power, we now direct our attention to nuclear energy. For this purpose, our present

concern will be limited to the controlled release of energy from two contrasting nuclear processes, *fission* and *fusion*.

Energy from Atomic Fission

In its initial stages, the fission reaction is dependent solely upon the isotope uranium-235. Uranium, as it occurs naturally, consists of three isotopes, uranium-234, uranium-235, and uranium-238, with abundances of 0.006, 0.711, and 99.283 percent, respectively. Of these, uranium-234 may be regarded as negligible. Natural uranium would then consist of uranium-235 and uranium-238, with the former constituting only one part in 141 of the whole.

The significance of uranium-235 lies in the fact that of the several hundred naturally occurring atomic isotopes, it is the only one that is spontaneously fissionable by the capture of slow or thermal neutrons. This isotope is accordingly, of necessity, the initial fuel for all subsequent power development based on the fission reaction. The average amount of energy released by uranium-235 per fission-event is approximately 200 million electron-volts (Mev), or 3.20×10^{-11} joules. One gram of uranium-235 contains 2.56×10^{21} atoms. Hence, the energy released by the fissioning of 1 gram of uranium-235 is 8.19×10^{10} joules. This is equivalent to the heat of combustion of 2.7 metric tons of coal, or of 13.7 barrels of crude oil. It also is approximately equal to 1 thermal megawatt-day. Accordingly, a nuclear power plant with a capacity of 1,000 electrical megawatts, and a thermal efficiency of 0.33, would consume uranium-235 at a rate of about 3 kilograms per day.

Burner, Converter, and Breeder Reactors. A physical assembly in which a controlled chain reaction occurs is known as a nuclear reactor. For fission reactions, these reactors are divided into three principal types, *burners*, *converters*, and *breeders*.

A burner reactor is one that consumes the naturally occurring fissile isotope, uranium-235, in the manner indicated in Figure 8.29. However, despite the enormous amount of thermal energy per gram released by the fissioning of uranium-235, a severe limitation is imposed upon the amount of energy obtainable from this source by the facts that uranium is a comparatively rare chemical element, and that uranium-235 represents only 1/141 of natural uranium. A way out of this difficulty, however, is afforded by the fact that is it possible to convert both nonfissionable uranium-238, comprising 99.28 percent of natural uranium, and thorium-232, comprising essentially the whole of natural thorium, into isotopes which are fissionable.

FISSION POWER REACTION

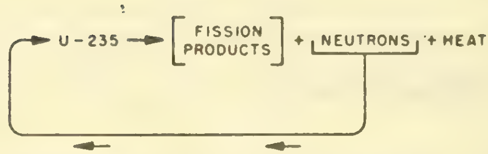

FIGURE 8.29
Schematic representation of nuclear-power-reaction from the fissioning of Uranium-235. (From Hubbert, 1962, Figure 56, p. 109.)

In each case, this is accomplished by exposing uranium-238, or thorium-232, to neutron bombardment, producing the following respective reactions:

$$^{238}_{92}U + n \rightarrow {}^{239}_{92}U \rightarrow {}^{239}_{93}Np \rightarrow {}^{239}_{94}Pu,$$

$$^{232}_{90}Th + n \rightarrow {}^{233}_{90}Th \rightarrow {}^{233}_{91}Pa \rightarrow {}^{233}_{92}U.$$

In this notation, the superscript denotes the total number of protons plus neutrons in the atomic nucleus, which also is approximately equal to the atomic mass; the subscript, which also is the atomic number and determines the chemical element, denotes the number of protons.

Thus, uranium-238 absorbs a neutron and is converted to uranium-239. The latter, by two short-lived radioactive transformations changes spontaneously to neptunium-239 and thence to plutonium-239. Similarly, thorium-232 absorbs a neutron and is transformed into thorium-233. This, in turn, changes radioactively into protoactinium-233 and thence into uranium-233. A flow diagram for the breeding reaction is shown in Figure 8.30.

Both plutonium-239 and uranium-233 are fissionable in a manner similar to uranium-235. The isotopes uranium-233, uranium-235, and plutonium-239, are accordingly known as fissile isotopes. Uranium-238 and thorium-232, on the other hand, which are not themselves fissionable, but are capable of being converted into previously nonexistent isotopes which are fissionable, are known as *fertile* materials. The process of converting fertile into fissile materials is known as *conversion*, or, in special cases, as *breeding*.

The thermal energy produced per fission by either plutonium-239 or uranium-233 is approximately the same as that produced by uranium-235, about 200 Mev. Since the atomic masses of uranium-238 and thorium-232 are very close to that of uranium-235, the numbers of atoms per gram are also very nearly the same. Hence, the thermal energy per gram obtainable

from natural uranium or thorium by means of conversion or breeding is approximately the same as from the initial fissile material, uranium-235, namely about 8.2×10^{10} joules per gram.

The neutrons required for conversion or breeding are those produced in a reactor whose initial supply of fuel is uranium-235. If uranium-238, or thorium-232, is placed in such a reactor, some of its atoms will absorb neutrons and become converted into its respective fissle isotope. The basic difference between conversion and breeding, is that by means of a conversion reactor, only a fraction of the fertile material can be converted into fissile material before the supply of the latter is completely exhausted. Whereas, for the breeder reactor, more fissile material is produced than is consumed, and it is possible, in principal, to utilize the entire supply of fertile material, provided that sufficient uranium-235 is available to start the process initially.

For the discussion of conversion or breeding, a significant quantity is that known as the *conversion ratio*. If Q_o be the initial amount of fissile material in the fuel inventory of a reactor, including its auxiliary fuel-processing equipment, and if Q be the amount of fissile material remaining after one cycle during which an amount of fuel Q_o has been consumed, the conversion (or breeding) ratio is defined by

$$K = Q/Q_o. \tag{9}$$

If $K = 0$, the reactor is a pure burner; if K is greater than 0, but less than 1, the reactor is a converter; and finally, if K is greater than 1, the reactor is a breeder.

Development of Nuclear Power. The foregoing principles are essential for an appraisal of the present status and future prospects of nuclear-power development based on atomic-fission reactors.

Historically, the technological evolution from the first experimental

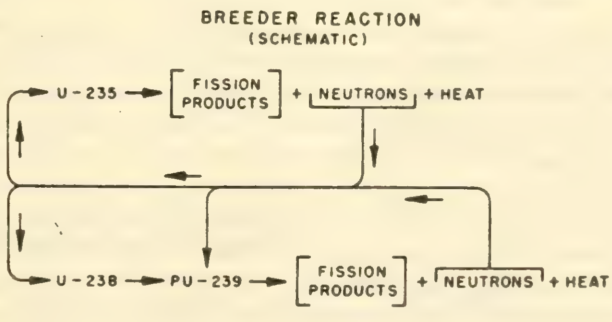

FIGURE 8.30
Schematic representation of breeder reaction for Uranium-238. (From Hubbert, 1962, Figure 57, p. 109.)

achievement of atomic fission to the present design and construction of nuclear power plants of 1,000 electrical-megawatt capacities occurred in an incredibly short time. Fission was first achieved experimentally in 1938, and the first controlled chain reaction on 2 December 1945. The first electric power was produced in 1951, and the first large-size nuclear-electric power plant—that at Shippingport, Pennsylvania, with an initial capacity of 60 electrical megawatts—went into operation in 1957.

However, in the United States, until about 1963, the development program was largely experimental, with emphasis on alternative designs and cost reduction, in an effort to make nuclear power economically competitive with that from fuels and water power. The latter achievement was reached in 1963 when a contract was let to the General Electric Company for the Oyster Creek plant of the Jersey Central Power Company. This was to have a capacity of 515 electrical megawatts and a guaranteed cost of power production below that of a comparable fuel-powered plant.

Following this, further contracts for additional plants in the 500 to 1,000 electrical megawatt range have followed in such profusion that they can best be considered statistically rather than individually.

As a consequence of this acceleration, the U.S. Atomic Energy Commission (AEC) has recently been obliged to increase significantiy its earlier forecasts of the growth of nuclear power. According to this latest estimate (U.S. AEC, 1967b, Table 5, p. 8), the median forecast for the nuclear-power capacity of the United States was for an increase from 1,800 electrical megawatts at the end of 1966 to 145,000 electrical megawatts by the end of 1980. This represents a mean exponential growth rate of 31 percent per year, with a doubling period of only 2.4 years. The corresponding forecast (ibid., Table 1, p. 3) for total U.S. electrical-power capacity for the same period was for an increase from 233,000 electrical megawatts at the end of 1966 to 579,000 by the end of 1980—a mean growth rate of 6.5 percent per year, with a doubling period of 10.6 years.

However, according to the AEC Annual Report for 1967 (U.S. AEC, 1968, p. 93, with the exception of two gas-cooled reactors, all of the central-station nuclear power plants ordered by utilities since 1958 are light-water reactors (as contrasted with heavy water). For present purposes, the distinctive characteristic of these reactors is that they consume uranium-235 as fuel, having such low conversion ratios that they are essentially burners. In the foregoing report (ibid., p. 86) it is stated that such reactors are capable of consuming only 1 to 2 percent of natural uranium or thorium. According to Milton Shaw (1968, Fig. 4), Director of the Division of Reactor Development and Technology, the cumulative production of plutonium by the light-water reactors up to any time between 1968 and 1980 will be approximately one-third of cumulative consumption of uranium-235 to that date. This corresponds to a total consumption of only 1 percent of natural uranium.

The significance of this is that these light-water reactors will effect a heavy drain on the lower-cost resources of uranium-235 if not soon supplanted by high-ratio converter or breeder reactors. As stated by Milton Shaw (ibid., p. 1), ". . . the phenomenal number of orders for nuclear power plants over the last three years . . . emphasizes the increasing importance of the timely introduction of breeder reactors into the utility environment. . . . It becomes more evident each day how dependent we are going to become on the successful introduction of breeders in order to be assured of practically limitless economic electric power and process heat."

The reason for this concern is clear when the magnitude of uranium resources is measured against the requirements between now and 1980. This situation has been succinctly reviewed by Rafford L. Faulkner, Director, Division of Raw Materials, U.S. Atomic Energy Commission, in his opening remarks before the Conference on Nuclear Fuel—Exploration to Power Reactors, Oklahoma City, Oklahoma, on 23 May, 1968. Using the AEC's most recent forecast of nuclear-power capacity to the end of 1980, Faulkner points out that, in addition to year-by-year current requirements, it will be necessary to maintain an 8-year forward reserve of uranium supply; that is, the total requirement to the end of 1980 must comprise not only the amount actually consumed to the end of 1980, but also the additional amount to be consumed during the next 8 years. This total figure he estimates to be about 650,000 tons of uranium oxide, U_3O_8.

To be compared with this requirement figure, Faulkner gives reserve estimates of uranium in three price ranges: (1) less than $10/lb of U_3O_8, (2) $10–15/lb, and (3) $15–30/lb. For each price range, two categories of reserves are given: those that are reasonably assured, and estimated additional reserves. A composite of the price estimates of both producers and buyers of uranium is $7.10/lb of U_3O_8 by 1970, and increasing to $7.80 by 1973. The reserves of less than $10/lb are accordingly the ones of principal interest at present. For this category, Faulkner gives for the United States:

Reasonably assured reserves	310,000 tons U_3O_8
Estimated additional	350,000
Total	660,000 tons U_3O_8

In the same category, the figures for the noncommunist countries of the world (including the United States) are:

Reasonably assured reserves	835,000 tons U_3O_8
Estimated additional	740,000
Total	1,575,000 tons U_3O_8

Against this world figure, however, allowance must be made for the fact that the growth of nuclear power outside the United States will probably be at a comparable rate to that in the United States.

From these figures, it is apparent that a very tight situation in uranium supply at anywhere near current prices is likely to develop within the next two decades. This surmise is confirmed by the U.S. Atomic Energy Commission in its report on civilian nuclear power (1967a), wherein, on page 14, the statement is made:

> With reactors of current technology, the known and estimated domestic resources of uranium at prices less than $10 per pound of uranium oxide (U_3O_8) are adequate to meet the requirements of the projected growth of nuclear electric plant capacity in the U.S. for about the next 25 years.

However, since that report was issued the estimate of nuclear power-plant capacity for 1980 has been increased from 95,000 to 145,000 electrical megawatts without a corresponding increase in the estimates of uranium reserves.

An even further restriction arises from the rate at which these reserves can be mined and processed. According to Faulkner, of the reasonably assured reserves of 310,000 tons of U_3O_8 in the United States, only about 210,000 tons can be produced by 1980. His corresponding estimate for cumulative world production is about 500,000 tons. This alone could force the low-priced reserves into a higher-price category in case, as appears likely, it should be necessary to double the rate of production.

Breeder-Reactor Program. This situation has forced the breeder-reactor program out of a state of lethargy into something more nearly resembling a crash program. A recent account of the program has been given by Milton Shaw, Director, Division of Reactor Development and Technology, U.S. Atomic Energy Commission, in his paper on "The U.S. Fast Breeder Reactor Program" given before the American Power Conference, Chicago, Illinois, on 23 April 1968.

According to Shaw, experimental work was begun by the U.S. Government as early as the late 1940's on the possibility of utilizing the almost limitless energy tied up in uranium-238 and thorium-232. This led to the experimental breeder-reactor program and to the construction and operation of several experimental breeder reactors of different designs, culminating in 1955 in the construction of the Enrico Fermi Atomic Power Plant in Michigan, the first large sodium-cooled fast breeder.

Nevertheless, on the whole, the program was diffuse and characterized by an atmosphere of complacency. The growth rate of nuclear power was seriously underestimated, and no scarcity of uranium resources was forseen.

During the 20-year period from 1948 through 1967, the budget for the entire AEC breeder program amounted to but $12,000,000 per year. "There was much less substance than image" according to Shaw, "in the industrial breeder program for there appeared to be ample time."

With the belated realization of the possibility of a crisis in the fuel supply, the breeder-reactor program is now being pushed with great vigor. A series of technical reviews concerning the status of the advanced breeder program was begun in 1965. About the same time, the unprecedented series of orders by the utilities for light-water reactors emphasized the need for a change of approach to the whole breeder-development program. Consequently, the development and introduction into utility usage of safe, reliable, and economic breeder-reactor power plants became the highest priority in the AEC's reactor-development program. In this program, the highest priority was given to the development of a liquid-metal cooled, fast-breeder reactor (LMFBR) utilizing the uranium-238–plutonium-239 cycle.

Accordingly, in 1966, the LMFBR Program Office (staffed currently with about 50 professional scientists and engineers) was established at the Argonne National Laboratory near Chicago to assist with the detailed planning and technical evaluation of various aspects of the LMFBR program. The time schedule on this program involves getting an initial power plant into operation by the early 1980's, and large commercial plants into operation between 1985 and 1990.

The program of breeder-reactor development is also reviewed in the 1967 annual report of the AEC (U.S. AEC, 1968, pp. 77–86), in which it is confirmed that the highest priority has been given to the development of the liquid-metal cooled, fast-breeder reactor, with the goal of achieving a safe, reliable, and economic 1,000 Mwe LMFBR plant in the 1980's.

In parallel with this, but of secondary priority, studies are being initiated on other types of breeders. The principal of these is the molten-salt breeder reactor (MSBR). This would be based on the thorium-232–uranium-233 cycle, and hence, as a user of thorium as a raw material, would be a highly desirable complement to the LMFBR using uranium-238.

The projected doubling times—the time required for the doubling of the initial fuel inventory—which it is hoped to achieve by these two types are about 10 years for the LMFBR, using the uranium-238–plutonium-239 cycle, and between 10 and 20 years for the MSBR, using the thorium-232–uranium-233 cycle. A doubling period of 10 years, assuming no uses of fissile material for nonbreeding purposes, would permit a maximum rate of growth of breeder-power production of about 7 percent per year; a doubling period of 20 years would allow a maximum growth rate of about 3.5 percent per year.

Another breeder, or possibly converter, program involves the modification of the present type of light-water reactors by means of adding blankets of

fertile materials to increase the conversion ratio. In this manner, it is hoped to increase the energy obtainable from natural uranium or thorium from the present approximately 1 percent to possibly as high as 50 percent. For natural uranium, 50 percent burnup would correspond to a conversion ratio of about 0.98.

Long-Term View of Nuclear-Fission Energy. Taking a view of not less than a century, were electrical power to continue to be produced solely by the present type of light-water reactors, the entire episode of nuclear energy would probably be short-lived. With the growth rates now being experienced, the inexpensive sources of uranium would probably be exhausted within a fraction of a century, and the contained uranium-235 irretrievably lost. With the use of more costly uranium, the cost of power would increase until nuclear power would no longer be economically competitive with that from fuels and water.

This unhappy conclusion cannot be evaded by improvements of conversion ratios by any amount short of breeding, because for any conversion ratio less than 1, the initial supply of uranium-235 as well as all new fissile material generated by conversion will eventually be consumed completely, leaving only the inert fertile materials. Hence, the only long-time benefit from conversion is to multiply by some finite amount the initial quantity of fissile material, and to increase somewhat the length of time for the exhaustion of the initial supply. If such a consequence is to be avoided, it can only be done by the supplanting, at the earliest date possible, of all power reactors having conversion factors less than unity by true breeder reactors.

Since this is technologically possible, as well as necessary, we shall now assume that the present episode of burner and converter reactors is but a temporary developmental phase, and that probably before the end of the present century they will be almost entirely superseded by breeder reactors. When this occurs, as Alvin Weinberg has pointed out repeatedly (e.g., 1959, 1960), the problem of raw materials for energy will be drastically modified. For under these circumstances, it will become possible and practicable to utilize truly low-grade ores of uranium and thorium which cannot at present be given consideration.

A couple of examples will suffice to illustrate this point. For a low-grade source of uranium, we may consider the Chattanooga Shale of Devonian age which crops out along the western Appalachians in eastern Tennessee and neighboring states, and underlies at minable depths a sizable fraction of the total areas of the states of Tennessee, Kentucky, Ohio, Indiana, and Illinois. According to Vernon E. Swanson (1960, p. 4) of the United States Geological Survey, the Gassaway Member of this shale is about 15 feet thick, extends over an area of hundreds of square miles, and contains about

0.0060 percent by weight of uranium. Let us consider the amount of energy which this represents, assuming the use of breeder reactors operating on the uranium-238–plutonium-239 cycle.

Here we deal with a layer of rock 5 meters thick having a density of 2.5 grams cm^3, or 2.5 metric tons per cubic meter, and a uranium content of 60 grams per metric ton, or 150 grams per cubic meter. Hence, for each square meter of surface area there are 5 cubic meters of rock containing 750 grams of uranium. As we have seen heretofore, the energy released by the fissioning of 1 gram of uranium is equivalent to that of the combustion of 2.7 metric tons of coal or of 13.7 barrels of crude oil. Therefore, the fuel equivalent of the uranium in 1 square meter of surface area would be 2,000 metric tons of coal or 10,000 barrels of crude oil. Per square kilometer, this would represent 2 billion metric tons of coal or 10 billion barrels of oil.

Rounding our previous estimates to 1,500 billion metric tons as the ultimate U.S. resources of producible coal, and about 200 billion barrels for producible crude oil, the areas for equivalent amounts of uranium are found to be 750 square kilometers for coal, and 20 square kilometers for oil. The area of 750 square kilometers for coal is about 300 square miles, or an area roughly 17 miles square. The 20-square kilometer area equivalent to the ultimate crude-oil resources would be only about 8 square miles, of an area somewhat less than 3 miles square.

For a similar calculation with regard to the energy obtainable from low-grade thorium deposits, using breeder reactors, we may consider the Conway Granite in New Hampshire. This is a granite which crops out over an area of about 300 square miles, or 750 square kilometers, and extends probably to some kilometers in depth. According to studies by John A. S. Adams and associates (Adams, Kline, Richardson, and Rogers, 1962), this granite has a remarkably uniform thorium content, averaging 56 grams per metric ton. In this case, 1 cubic meter of rock has a mass of 2.7 metric tons and contains 150 grams of thorium. Since the energy released by fissioning of 1 gram of thorium is substantially the same as for uranium, the fuel equivalent of the thorium contained in a cubic meter of rock is equivalent to about 400 metric tons of coal, or 2,000 barrels of crude oil.

Should the whole area be quarried to a depth of only 100 meters (330 feet) and the thorium used in breeder reactors, the fuel equivalent of the energy produced would be 30×10^{12} metric tons of coal, or 150×10^{12} barrels of crude oil. This would be 20 times the coal resources of the United States, or 750 times the resources of crude oil.

These are only illustrative examples. The energy potentially obtainable by breeder reactors from rocks occurring at minable depths in the United States and containing 50 grams or more of uranium and thorium combined per metric ton is hundreds or thousands of times larger than that of all of the

fossil fuels combined. It is clear, therefore, that by the transition to a complete breeder-reactor program before the initial supply of uranium-235 is exhausted, very much larger supplies of energy can be made available than now exist. Failure to make this transition would constitute one of the major disasters in human history.

Energy from Fusion

In 1939, H. A. Bethe (1939a; 1939b) published the results of theoretical studies of the preceding year in which he derived from primary data the sequence of nuclear reactions whereby the enormous amounts of energy radiated from the sun and the stars are produced by the fusion of hydrogen of atomic-mass 1 into helium of atomic-mass 4[1]. Since that time, the question of whether controlled fusion may also be achieved in the laboratory has been a continuing challenge.

The chemical element hydrogen has three isotopes of mass numbers 1, 2, and 3, which have now come to be known by the separate names of *hydrogen* with the chemical symbol H, *deuterium* with the symbol D, and *tritium* with the symbol T, respectively. The problem of achieving controlled fusion reduces to that of fusing two or more of these isotopes of hydrogen into helium, the next higher element in the atomic scale. Helium also has two isotopes of present interest, helium-3 and helium-4.

The fusion of deuterium and tritium into helium in an uncontrolled explosive manner has already been achieved and is the basis for the so-called hydrogen, or thermonuclear bomb. Research in an effort to achieve a controlled fusion reaction has been under way in several laboratories in the United States during the last two decades, and comparable work is being conducted in several other countries. However, the British government has recently announced its intention of discontinuing the fusion work being conducted there. Although progress toward the achievement of controlled fusion is gradually being made, it still is not possible to estimate when, or even whether, the development of power from the fusion reaction may ever be accomplished. However, since the possible fusion reactions and their associated energy releases are known, it is possible to estimate the amounts of energy potentially obtainable from these reactions in terms of the earth's resources of the primary isotopes involved.

According to Samuel Glasstone (1964) of the U.S. Atomic Energy Commission, the most hopeful approaches to the achievement of controlled fusion are those that involve the fusion of two deuterium atoms, or of one deuterium and one tritium atom. Of these two, the latter appears to be the one more likely to be successful, at least initially.

[1] For this work Bethe was awarded a Nobel Prize in 1968.

The reactions of interest, and their associated energy releases, are the following:

$$^{2}_{1}D + ^{2}_{1}D \rightarrow ^{3}_{2}He + n + 3.2 \text{ Mev},$$

$$^{2}_{1}D + ^{2}_{1}D \rightarrow ^{3}_{1}T + H + 4.0 \text{ Mev}.$$

Here, in addition to the chemical symbols already defined, n is a neutron and Mev signifies a million-electron volts, which is equal to 1.60×10^{-6} ergs or to 1.60×10^{-13} joules.

These two reactions are about equally probable. In the first, a stable product is produced, but in the second, the tritium atom reacts with another deuterium in the following manner:

$$^{2}_{1}D + ^{3}_{1}T \rightarrow ^{4}_{2}He + n + 17.6 \text{ Mev}.$$

Therefore, the net result of these three reactions can be written in the form

$$5\,^{2}_{1}D \rightarrow ^{4}_{2}He + ^{3}_{2}He + H + 2n + 24.8 \text{ Mev}.$$

Hence, the energy released per deuterium atom in these fusion reactions would be 4.96 Mev.

Further interest attaches to the deuterium-tritium reaction in view of the fact that another way exists for producing tritium atoms. When lithium-6 is bombarded with neutrons the following reaction occurs:

$$^{6}_{3}Li + n \rightarrow ^{4}_{2}He + ^{3}_{1}T + 4.8 \text{ Mev}.$$

When this is combined with the tritium-deuterium reaction,

$$^{3}_{1}T + ^{2}_{1}D \rightarrow ^{4}_{2}He + n + 17.6 \text{ Mev},$$

the net result is equivalent to the reaction

$$^{6}_{3}Li + ^{2}_{1}D + n \rightarrow 2\,^{4}_{2}He + b + 22.4 \text{ Mev}.$$

In this reaction, the limiting condition depends on the relative abundance of lithium and deuterium. The magnitude of total energy potentially obtainable will be limited by whichever isotope is the more scarce.

Let us now consider the amounts of energy that would be made potentially

available in each case should the deuterium-deuterium, or the lithium-deuterium fusion reaction be achieved.

Energy from D-D Fusion. In the case of deuterium fusion, we have already seen that the release of energy per deuterium atom would amount to 4.96 Mev which is equivalent to 7.94×10^{-13} joules. The relative abundance of deuterium in water (including sea water) is 1 deuterium atom for each 6,500 hydrogen atoms. From these data, together with the respective atomic weights and Avogadro's number, it may be determined that 1 cubic meter of water contains about 1.028×10^{25} atoms of deuterium having a mass of 34.4 grams, and a potential fusion energy of 8.16×10^{12} joules. This is equivalent to the heat combustion of 269 metric tons of coal, or of 1,360 barrels of crude oil.

Since a cubic kilometer contains 10^9 cubic meters, if follows that the fuel equivalents of 1 cubic kilometer of sea water are 269 billion tons of coal, or 1,360 billion barrels of crude oil. The latter figure is approximately equal to the lower of the two estimates of ultimate world resources of crude oil. Since the ultimate world coal resources as estimated by Averitt are about $7{,}600 \times 10^9$ metric tons, the volume of sea water required to be equivalent to this would be about 28 cubic kilometers. The total volume of the oceans is about 1.5×10^9 cubic kilometers. Should enough deuterium be withdrawn to reduce the initial concentration by 1 percent, the energy released by fusion would amount to about 500,000 times that of the world's initial supply of fossil fuels.

Energy from Lithium-Deuterium Reaction. Consider now the energy potential obtainable from the lithium-deuterium reaction. The amount of this energy will be limited by whichever of the two isotopes is in shortest supply. From our previous calculations, we found that there are about 1025 atoms of deuterium per cubic meter of sea water. This would be 1034 deuterium atoms per cubic kilometer, or a total of about 1.5×10^{43} atoms in total volume of the oceans. And a large fraction of this could readily be extracted at low cost by methods now in use.

Lithium, on the other hand, is found in readily extractible concentrations only in restricted localities on land. The geochemical abundance of lithium in sea water is only about 1 part in 10 million, and recent estimates (Parker, 1967, Table 20) for the average abundance of lithium in the crustal rocks of the earth all fall within the range of 20–32 parts per million. However, the isotope, lithium-6, required for fusion constitutes only 7.42 percent of natural lithium. Hence, lithium-6 is present in a concentration of but 7 parts per billion in sea water, and about 2 parts per million in the crustal rocks of the earth.

Minable deposits of lithium occur principally in the mineral spodumene in

igneous pegmatites, and in concentrations of natural brines. As recently as 1965, the sum of the measured, indicated, and inferred reserves of Li_2O in the United States, Canada, and Africa, were estimated by James J. Norton of the U.S. Geological Survey, (unpublished) to be about 1.6 million metric tons. Comparable estimates have been published by Thomas L. Kesler, Chief Geologist of the Foote Mineral Company, the largest lithium producer in the United States (Kesler, 1960; 1961). These estimates include about 2 million metric tons for the United States, 390,000 for Canada, and 180,000 for Africa.

The Foote Mineral Company has begun exploitation of a brine deposit near Silver Peak, Nevada, which is reported (Foote Mineral Co., 1967) to contain reserves of 2.5 to 5 million short tons of lithium. This deposit alone would correspond to about 5 to 10 million metric tons of Li_2O. In addition, the brine of Great Salt Lake, Utah, with a lithium content of 0.006 percent, is beginning to be processed for this element by the Lithium Corporation of America.

In view of the large but only roughly known magnitudes of the lithium reserves in the Silver Peak and Great Salt Lake brines, Norton considers 10 million short tons of elemental lithium to be a good order-of-magnitude estimate of the presently known resources of lithium in the United States, Canada, and Africa. Using this figure and the previous estimates for Canada and Africa, revised lithium reserves of these three areas are shown in Table 8.10. Also, in each instance, the amount of the isotope lithium-6 is given in metric tons. From the latter figures, the number of lithium-6 atoms can be obtained from the relationship,

$$\frac{\text{Avogadro's number}}{\text{Atomic weight, }^6\text{Li}} = \frac{6.0225 \times 10^{23}}{6.015 \text{ grams}}$$

$$= 1.0 \times 10^{23} \text{ atoms per gram.}$$

Then, since 1 metric ton $= 10^6$ grams, there are 1.00×10^{29} lithium-6 atoms per metric ton.

From the fourth column of Table 8.10, it is seen that the number of atoms of lithium-6 in the known lithium reserves of North America and Africa is about 7×10^{34}. Since this number is of the order of a hundred-millionth of the 1.5×10^{43} deuterium atoms in the oceans, it follows that the amount of energy potentially obtainable from the lithium-deuterium fusion reaction will be limited by the scarcity of lithium-6 rather than of deuterium. Accordingly, we may ascribe the total energy of 22.4 Mev, or 3.58×10^{-12} joules, obtainable from each atom of lithium-6 consumed, to the lithium-6 alone. On this basis, the energy potentially obtainable by the consumption of the amounts of lithium-6 shown in column 4 is given in column 5 of Table 8.10. This amounts to a total of about 2.4×10^{23} joules,

TABLE 8.10
Estimated lithium reserves of the United States, Canada, and Africa.

Location	Li_2O Measured, indicated, and inferred[a] (10^6 metric tons)	Lithium metal (10^6 metric tons)	Lithium-6 (10^4 metric tons)	Number of lithium-6 atoms (10^{33} atoms)	Equivalent fusion energy (10^{21} joules)
United States	19.0	8.8	65.4	65.4	234
Canada	0.4	0.2	1.4	1.4	5
Africa	0.2	0.1	0.7	0.7	2.5
Total	19.6	9.1	67.5	67.5	241.5

[a] Figures based on data from James J. Norton, U.S. Geol. Survey, Thomas L. Kesler (1961), and Foote Mineral Co., (1967).

which is approximately equal to the figure of 2.6×10^{23} joules for the energy obtainable from the combustion of the world's initial supply of fossil fuels.

Hence, unless much larger quantities of lithium of a lower grade than those now mined should be exploited, the scarcity of lithium renders the lithium-deuterium fusion reaction a much less promising ultimate source of energy than the deuterium-deuterium reaction. However, should the controlled lithium-deuterium reaction be the first to be achieved, it is technologically probable that achievement of the deuterium-deuterium reaction would follow.

DISPOSAL OF RADIOACTIVE WASTES[2]

An essential requirement for a nuclear-power industry based on the fission reaction[3] is a system for the safe management and disposal of radioactive wastes.

All common matter on earth is radioactive in some degree. Organisms on the earth are subjected continuously to a low level of damaging radiation from the radioactivity inside their tissues, from that of their immediately surrounding environment, and from cosmic rays. Men and other animals have evolved physiological systems able to repair tissue damage from "background" radiation at about the same rate the damage occurs. However, if the radiation rate is significantly increased, such repair is no longer possible, and permanent injury results. Depending on the nature of the exposure, radiation injuries take many forms, ranging from small and long-delayed effects to short-term lethal effects; a subtle and serious consequence of some radiation injuries is genetic transmission of physiological defects.

Radioactive wastes are distinguished from all other kinds of noxious wastes of chemical origin by the fact that there is no method of treating them to counteract their innate biological harmfulness. Radioactivity, a nuclear phenomenon, cannot be changed by any process less drastic than that which occurs inside nuclear reactors. Each radioactive isotope decays at a fixed negative-exponential rate peculiar to itself.

Health physicists and others have determined standards for the maximum concentration of radioactivity from different radioactive materials that is considered safe for human or other biological exposure. These maximum safe concentrations are different for different isotopes, but as a practical generalization the Health Physics Division of the Atomic Energy Commission

[2]Prepared by Earl Cook, Texas A&M University, from notes provided by M. King Hubbert.

[3]In the alternative fusion reaction the end product is mainly nonradioactive helium.

has used 20 half-lives[4] as the minimum period a given type of high-level radioactive waste should be permitted to decay before being considered safe for biological exposure. This rule would require that wastes containing the long-lived isotopes strontium-90 and cesium-137, which have half-lives of 28 and 30 years, be isolated at least 600, and possibly as long as 1,000 years, to render them biologically harmless.

Radioactive wastes are produced mainly by the "burning" of the fissile fuel, and to a much lesser extent by neutron bombardment of otherwise neutral materials within the reactor, including reactor metals, coolant fluids, and air or other gases. *The mass of radioactive fission prod ːts produced in a reactor is very nearly equal to the mass of fuel consumed.*

Inside a reactor, the fuel elements are encased in metal containers which retain the fission products produced. After a certain percentage of "burnup" of the initial fuel, the fuel elements are removed from the reactors and taken to fuel-processing plants where the fission products are separated chemically from the unspent fuel, which is then refabricated into new fuel elements. As they come from the reactor the fission products represent a wide scatter of isotopes, the composite of which is highly radioactive.

Most radioactive waste is generated in the fuel-processing plants and is in liquid or slurry form; it is stored in tanks of steel, or of steel and concrete, for a preliminary period of "cooling" before disposition as waste. The principal solid wastes are radioactive trash (contaminated boxes, rags, and laboratory apparatus) and reactor and machinery parts that have acquired an induced radioactivity from neutron bombardment. Radioactive liquids or slurries are classified as high-level when their radioactivity is greater than 1 curie[5] per gallon, intermediate-level for radioactivities between 1 microcurie (10^{-6} curies) and 1 curie per gallon, and low-level for less than 1 microcurie per gallon.

In 1955, at the request of the Atomic Energy Commission, an advisory Committee on the Geologic Aspects of Radioactive Waste Disposal was established by the Division of Earth Sciences of the National Academy of Sciences—National Research Council. This committee, which included geologists, ground-water hydrologists, and mining and petroleum engineers, served until 1967, and made a succession of study visits to most of the AEC establishments concerned with management and disposal of radioactive wastes. The committee formulated three general principles on which any long-term program of disposal of radioactive wastes should be based. These principles may be paraphrased as follows:

1. All radioactive materials are biologically injurious. Therefore, all

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[4] A half-life is the time required for any given species of radioactive material to disintegrate or decay to one-half its original mass.

[5] A curie is a measure of the rate of radioactive disintegration; it equals a rate of 3.7×10^{10} disintegrations per second, about the disintegration rate of 1 gram of natural radium.

radioactive wastes should be isolated from the biological environment during their periods of harmfulness, which for the long-lived isotopes exceeds 600 years.

2. The rate of generation of radioactive wastes is roughly proportional to the rate of power production from nuclear-fission reactors. In the period of its work, the committee regarded the rate of nuclear power and related radioactive-waste production as being on the very low portion of a steep exponential-growth curve. The committee therefore reasoned that no waste-disposal practice, even if regarded as safe at an initially low level of waste production, should be initiated unless it would still be safe when the rate of waste production becomes orders of magnitude larger.

3. No compromise of safety in the interest of economy of waste disposal should be tolerated.

These principles are still valid.

Present practices which satisfy these principles best are those pertaining to the high-level wastes that emerge from the chemical processing of spent reactor fuel elements. These extremely radioactive aqueous-solid slurries generate heat at rates as high as 200 watts per gallon (Zeitlin and Ullmann, 1955), and it is necessary to store them a year or more to dissipate thermal energy before attempting more permanent storage or disposal.[6]

For permanent storage, the AEC has a number of possible procedures under research and development at present (U.S. AEC, 1968; Fox, 1967).

One possibility is to retain the self-dessicated slurries permanently in the original storage tanks. More promising procedures involve reduction of the wastes to solids in the form of glass or ceramic slugs, or calcined granules. These solids can then be buried in natural salt beds or stored in concrete-and-metal bins on or near the earth's surface. In either case, the high-level radioactivity of the solids will be isolated from circulating ground water and from the biological environment. Of the two alternatives, underground storage in salt, which is highly impervious to ground-water flow, appears preferable.

Present practices with regard to intermediate- and low-level aqueous wastes, of gaseous wastes, and of radioactive trash, are less satisfactory. The large amounts of water involved in low-level aqueous wastes make the problem of concentrating the radioactive isotopes difficult. Oak Ridge National Laboratory puts intermediate-level wastes into slurry form and injects the slurry into hydraulically induced fractures at a depth of about 700–1,000 feet in shale, where the slurry "sets" as a solid. In the Oak Ridge locality these fractures appear to be principally horizontal, or parallel to the bedding planes of the shales, and there seems *little* chance that radioactivity will escape upward. In most areas, however, oil-industry experience shows hydraulically induced fractures to be vertical and therefore unfavorable to

[6]Storage implies that the material is retrievable; disposal, that it is not.

safe disposal by injection. In consequence, it is questionable whether the Oak Ridge practice can be extended to other areas without going to much greater depths in the interest of safety. In any area, the wastes should be placed below the level of circulating potable ground water.

At the Hanford Works in Washington and at the National Reactor Test Station in Idaho, intermediate-level wastes are either stored in earth ponds or discharged underground through special cribs. At both localities, low-level wastes are discharged through wells into the subsurface body of circulating ground water. In Great Britain and possibly elsewhere, low-level wastes are being discharged directly into the sea.

At most of the AEC localities, and at several sites recently authorized for operation by private industry, solid wastes are buried in trenches 10–15 feet deep and covered with soil. Although these trenches are above the ground-water table, they are within the domain of circulating soil moisture, some of which returns to the surface by evaporation and plant transpiration, and some of which descends to the water table.

Radioactive gases, after removal of most of the longer-lived isotopes and a period of storage of the rest, are discharged through tall dispersion stacks into the atmosphere.

From this brief outline, it can be seen that most present practices in the disposal of radioactive wastes *other than high-level liquid* violate the first of the three principles stated above, and probably the second also. These wastes are not being isolated from the biological environment at present, and it is questionable to what extent the same practices can be continued when the rate of waste production becomes 10 or 100 times larger than it is at present without causing serious hazard.

With regard to the third principle, which deals with the possible compromise of safety by economy, it should be pointed out that management costs for high-level wastes in the United States at present (Fox, 1967, p. 15) is less than 1 percent of the total cost of nuclear-power production. The cost of the entire waste-management program probably does not exceed 2 percent. In other words, the cost problem is not formidable. Nor is the physical problem intractible, for the rate of production of radioactive isotopes in the United States at present (1968) is only a metric ton or two per year.

It is more than penny-wise and pound-foolish to skimp on budgets for radioactive waste-disposal programs and to adopt *expedient* practices for economic reasons; it is hazardous to the health and genetic security of the nation.

A new monitoring system for radioactive-waste disposal practices is needed. This system must be independent of the agencies and organizations that produce such wastes, and would be somewhat analogous to the system of financial auditing which has been found both essential and effective in monetary affairs. Furthermore, reports generated by the group or body

charged with operation of this monitoring system should be public, for every citizen is a shareholder in the common good.

HUMAN AFFAIRS IN TIME PERSPECTIVE

From the foregoing review, it is evident that the fortunes of the world's human population, for better or for worse, are inextricably interrelated with the use that is made of energy resources. Although the human species has always used energy to meet its minimum biological requirements, it is only within recent centuries, with the advent of energy from the fossil fuels and from wind and water power, that mankind has been able to increase its energy utilization per capita significantly above this minimum level. Despite the fact that the exploitation of these sources of energy has had a history extending over a period of several centuries, most of the developments during this entire period have occurred since 1900.

A much better perspective of the state of human affairs, and of the prospects for the future, can be obtained if the events in which we are concerned are regarded on a time scale of some tens of thousands of years. On such a scale, the quantities whose growth with respect to time we have been considering—the world's human population, the consumption of energy per capita, the development of water power, and the exploitation of the energy from fossil fuels—would all plot as curves with such uniform similarities as to be almost indistinguishable from one another. The curve of human population, for example, would plot as a nearly horizontal line just above zero for the entire period of human history until the last thousand years or so. Then a barely perceptible rise would begin and, as the present is approached, the curve would turn abruptly upward and rise nearly vertically to the 1969 world-population figure of about 3.5 billions.

The curve of the rate of energy consumption per capita would behave in a similar manner. Beginning with the biological minimum of about 100 thermal watts per capita represented by food, this curve would rise very slowly as other sources of energy—particularly that of firewood—are added, until it stabilized at about 500 thermal watts per capita. Then, a few centuries before the present when the exploitation of the energy from coal and of the power from water and wind was begun, this curve too would begin a slow and barely perceptible rise until, as the present is approached, it also would turn nearly vertically upward to a height of about 10,000 thermal watts per capita, which is the present average for the United States.

The curves of energy production from the fossil fuels would behave in a similar manner except that in the very recent past these would begin at zero.

Looking into the future on the same time scale, and assuming that a

catastrophic event such as the near annihilation of the industrialized world by thermonuclear warfare can somehow be avoided, the physical realities discussed in this book dictate that the curve of human population must follow one of three possible courses: (1) It could continue to rise for a brief period and then gradually level off to some stable magnitude capable of being sustained by the world's energy and material resources for a long period of time; (2) it could overshoot any possible stable level and then drop back and eventually stabilize at some level compatible with the world's resources; or (3), finally, as a result of resource exhaustion and a general cultural decline, the curve could be forced back to a population corresponding to the lowest energy-consumption level of a primitive existence.

The one type of behavior for this curve that is not possible is that of continued and unlimited growth. To see that limits do exist, one need only consider that if the present world population were to be doubled but 15 more times, there would be one man for each square meter on all of the land areas of the earth, including Antarctica, Greenland, and the Sahara Desert. And at the present rate of growth, this would require but 525 more years.

Considering the other curves discussed previously, that of the production of the fossil fuels would continue upward for a brief period, and would then decline about as abruptly as it arose.

To sustain a high-energy-dependent world culture for a period much longer than a few centuries requires, therefore, a reliable source of energy of appropriate magnitude. The largest and most obvious of such sources is solar radiation, the continuance of which at close to present rates may be relied upon for millions of years into the future. The energy from solar radiation, with the exception of that fraction manifested as water power, does not offer much promise as a means of large-scale power production, although future technology may circumvent this difficulty. This leaves us with nuclear energy as our only remaining energy source of requisite magnitude. Although the earth's resources of uranium and thorium, and of deuterium, are finite and therefore exhaustible, the magnitudes of these resources in terms of their potential energy contents are so large that with breeder and fusion reactors they should be able to supply the power requirements of an industrialized world society for some millenia. In this case, the limits to the growth of industrial activity would not be imposed by a scarcity of energy resources, but by the limitations of area and of the other natural resources of a finite earth.

It now appears that the period of rapid population and industrial growth that has prevailed during the last few centuries, instead of being the normal order of things and capable of continuance into the indefinite future, is actually one of the most abnormal phases of human history. It represents only a brief transitional episode between two very much longer periods, each characterized by rates of change so slow as to be regarded essentially

as a period of nongrowth. It is paradoxical that although the forthcoming period of nongrowth poses no insuperable physical or biological problems, it will entail a fundamental revision of those aspects of our current economic and social thinking which stem from the assumption that the growth rates which have characterized this temporary period can be permanent.

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TOWARDS A NATIONAL MATERIALS POLICY • BASIC DATA AND ISSUES AN INTERIM REPORT • APRIL 1972

NATIONAL
MATERIALS POLICY

THE NATIONAL COMMISSION ON MATERIALS POLICY
WASHINGTON, D.C.

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CONTENTS

FOREWORD

The purpose of this interim report of the National Commission on Materials Policy is to serve as a working paper for those interested and involved in the activities of the Commission. It provides background information on the Commission's assignment and tasks. It presents statistical data and information that hopefully will provide a common base for the deliberations leading to the formulation of a National Materials Policy. And it outlines broadly many of the issues that have emerged from studies to date.

Because this is an interim report, it makes no claim to completeness or finality. The gathering of data and information and defining of issues that will be continued in the months ahead by many groups with widely diverse interests, will undoubtedly modify the report's content. This interim report, therefore, should be considered as only a beginning.

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INTRODUCTION

We live in a world of materials. Our shelter, clothing, and all the tools and products of our civilization are composed of natural and man-made materials. Twenty percent of the Nation's economy is engaged in providing materials and energy in usable form to society. Because of this pervasive importance of materials, the development of national policies to assure adequate future supplies and proper use of materials should be a key element in the Nation's planning efforts.

In the past, relatively little attention has been given to our national materials problems. Because the North American continent seemed to have been blessed with boundless resources, our nation has taken materials for granted and has assumed that the sources of our materials and energy are infinite.

However, based on our knowledge now of need-trends and of readily accessible supplies, we must reassess our long-standing attitudes, assumptions and policies on materials. The nation's vigorous industrial and economic growth over the past century has resulted in the highest standard of living in the world. Our complacency, however, has resulted in our failure to develop new materials sources as fast as required by the economy. As a consequence, the United States is increasingly dependent upon foreign sources. Today we are actively competing with the other industrial nations of the world for the presently known and available low cost resources. At the same time, the developing nations, too, are seeking increasing quantities of raw materials as they industrialize and attempt to raise their populations above the levels of mere subsistence.

Thus, if this country is to continue to prosper and if the standard of living of the presently under-developed areas of the world is to be raised to even a fraction of that enjoyed by the peoples in the industrial nations, a many-fold increase in raw materials supplies will be needed in the years ahead.

But our concern with materials does not end with the question of adequate supplies for future generations. The new factor of environmental quality has now been added to the equation. As more and more raw materials are extracted from the earth and processed and then consumed as products, more and more waste materials are produced and threaten to degrade the environment. Also, our production and consumption system, operating largely on a one-time-use-of-materials basis, generates additional, large quantities of waste. While some of the wastes gradually return to nature, a large share of them remain for long periods of time to degrade the environment if left untreated.

Over the past decade, it has become increasingly evident that we must find ways to establish an acceptable balance between materials needs and environmental quality. And it is likewise clear that we must shift from the use and discard approach toward a closed cycle of use, salvage, reprocess, and reuse, not only to preserve our environment, but also to extend our raw materials supplies.

Finally, as stated in the Foreword, this report is only the beginning of the process that will lead to a recommended national materials policy. Because materials occupy such a preeminent position in our civilization, their supply and use influence and are influenced by a wide range of forces in our world system. These will require definition, discussion and analysis. Perhaps the most important of these related factors are the rate of population and economic growth. Besides, these there are many other social, cultural, political and economic forces interacting with the materials production-use-disposal cycle. In addition, present and potential shifts in national goals and priorities must be taken into account. Thus, besides concern with the environment, the new emphasis in such areas as urban renewal, housing, transportation, medical care, and consumer services, will have a strong impact, not only on materials supply, but also on the kinds of materials that will be needed in the years ahead. As the work of the Commission proceeds, issues in these broad sectors will emerge and will have to be studied in the light of future realities.

ESTABLISHMENT AND OBJECTIVES OF THE COMMISSION

To develop national policies that will assure adequate future materials supplies while maintaining an acceptable environmental quality level, the National Commission on Materials Policy was established by Congress under Title II of the Resource Recovery Act of 1970 (called the National Materials Policy Act).

The Commission has a direct precedent in a previous Materials Policy Commission, which issued its report, "Resources for Freedom," in 1952. Although, the report was widely recognized for its far-reaching recommendations, it failed to generate significant legislative action.

The events that lead to the present Commission began in July 1967 when the Legislative Reference Service of the Library of Congress was asked to undertake a study of the relation of materials to the problems of solid waste disposal. A report, "Availability, Utilization, and Salvage of Industrial Materials," came out of this initial study. Subsequently, an ad hoc committee of materials experts, organized to examine in more detail the need for a national materials policy, issued a report, "Toward a National Materials Policy," that recommended the creation of a National Commission on Materials Policy. Legislation to establish such a commission was introduced in the Senate as an amendment to pending solid waste legislation in September 1969. This legislation became law in October 1970.

The general objective and assignment of the Commission is stated in the act as follows;

"It is the purpose of this title to enhance environmental quality and conserve materials by developing a national materials policy to utilize present resources and technology more efficiently, to anticipate the future materials requirements of the Nation and the world, and to make recommendations on the supply, use, recovery, and disposal of materials."

The act goes on to spell out the Commission's tasks in somewhat more detail:

"The Commission shall make a full and complete investigation and study for the purpose of developing a national materials policy which shall include, without being limited to, a determination of—

(1) National and international materials requirements, priorities, and objectives, both current and future, including economic projections;

(2) The relationship of materials policy to:

(A) National and international population size, and

(B) The enhancement of environmental quality;

(3) Recommended means for the extraction, development, and use of materials which are susceptible to recycling, reuse, or self destruction, in order to enhance environmental quality and conserve materials;

(4) Means of exploiting existing scientific knowledge in the supply, use, recovery, and disposal of materials and encouraging further research and education in this field;

(5) Means to enhance coordination and cooperation among Federal departments and agencies in materials usage so that such usage might best serve the national materials policy;

(6) The feasibility and desirability of establishing computer inventories of national and international materials requirements, supplies, and alternatives; and

(7) Which Federal agency or agencies shall be assigned continuing responsibility for the implementation of the national materials policy."

For the Commission's purposes, the act defines materials as ". . . natural resources, intended to be utilized by industry for the production of goods, with the exclusion of foods." The Commission's interpretation of its scope also includes energy materials and water.

INTEREST SECTORS

In order to develop a comprehensive national materials policy, the Commission is seeking and enlisting the aid of many diverse groups. Seven sectors of American society have been identified as having significant interests in materials. They are consumers, all levels of governments, industry, environmentalists, academia, the science and technology community, and labor. The Commission is working with all of these groups in a cooperative effort to understand their role and interests in materials, to elicit their views, and to take into consideration their positions in the policy formulation process.

In the Government sector, the Commission has formed an Interagency Steering Committee composed of representatives from all Federal departments and agencies having interests and responsibilities in the materials area. The individual agencies, acting through the steering committee, have provided the basic supply/demand data contained in this interim report. They also are identifying major materials problems facing the country and the world. Industry, through a number of trade associations, is identifying the major materials-related issues facing their respective industries now and in the future and, where possible, is suggesting possible solutions. Organized labor, through the AFL/CIO, has been asked to develop a mechanism that will present labor's knowledge and views on industrial materials.

The academic community will provide its input through a series of eight regional forums to be held in the spring of 1972 at eight prominent universities. Experts from various disciplines, such as materials scientists, materials engineers, political scientists, ecologists, and industrial managers, will debate selected major issues and develop policy recommendations. And the science and technology community, through the National Materials Advisory Board of the National Research Council of the National Academies of Sciences and Engineering, is working with the Commission on designated problems of materials policy.

To cover the environmental aspects of the Commission's work, responsible environmental groups and spokesmen are being asked to participate to assure that the vital national and world interests in maintaining a high quality environment are given due consideration. And, finally, the Commission is developing approaches to consumers, the fulfillment of whose needs and interests is one of the principle objectives in the formulation of any national materials policy.

THE NATION'S MATERIALS NEEDS AND SUPPLIES

The factual or data base for the discussions and deliberations, which will lead to the formulation of a materials policy, are contained in the appendices to this report. Summaries of demand/supply projections on the major families of materials are given in Appendix A, and the supporting data tables are given in Appendix B. The summaries and data are taken from information and projections furnished by the Departments of Interior, Commerce, and Agriculture, and the Atomic Energy Commission. Some information on recovery and recycling of nonferrous metals was obtained from an unpublished study conducted by the National Association of Secondary Material Industries for the Environmental Protection Agency. (Principal research by Battelle Memorial Institute, Columbus, Ohio).

The projections are carried out to the year 2000. Admittedly, in our rapidly changing world it is difficult to see ahead accurately even one or two years. Nevertheless, for planning purposes, it is necessary to postulate future conditions in order to formulate policies. However, when reviewing or using the summaries and data, it should be remembered that they do not represent a probable forecast of the future, but strictly a set of projections suitable as bench marks against which the effects of possible changes in policies and economic conditions can be considered. They provide a means of defining the problems and identifying the areas in which corrective actions may be needed.

It is clearly evident from the commodity summaries and the projections that in the case of a majority of our basic materials, the gap between our requirements and the remaining easily accessible world supplies is widening. The data further indicates that our reliance on foreign supplies is steadily increasing. Except for a short period during World War I, we were, on balance, a net exporter of minerals until shortly before World War II. Since then, with minor exceptions,

we have imported far more minerals than we have exported. This annual deficit has increased steadily during the last 20 years until in 1970 our imports of all minerals were valued at about $9 billion while exports were about $5 billion, a net deficit of about $4 billion. If trends of the past 20 years continue to the year 2000, this deficit could grow to over $60 billion a year.

In 1970 we imported all of our primary requirements for chromite, columbian, mica, rutile, tantalum, and tin; more than 90 percent of our aluminum, antimony, cobalt, manganese, and platinum; more than half of our asbestos, beryl, cadmium, fluorspar, nickel, and zinc; and more than a third of our iron ore, lead, and mercury.

As the accompanying table shows, world production of 31 minerals (the principal minerals entering into world import-export trade) increased from $37.1 billion 1968 U.S. dollars in 1950 to $77.4 billion in 1968 (later figures not yet available), while production of these same minerals in in the United States increased only from $14.2 billion to $18.5 billion. However, during the same period U.S. consumption of these minerals increased from $15.5 billion to $21.6 billion. Thus, while U.S. consumption increased nearly 40 percent in absolute terms, our consumption of total world production declined from 42 percent in 1950 to 28 percent in 1968.

The unmistakable conclusion reflected in the data and commodity summaries is that as the Nation's needs continue to grow and as per capita consumption of materials in other countries increases at an even faster rate than ours, it becomes increasingly difficult for the United States to fill its ever-growing deficit by imports, even at increasing prices.

World Production and Consumption of Selected [1] Minerals

(Values in Billions of 1968 U.S. Dollars)

	Production					Consumption			
	World	United States		Rest of the World		United States		Rest of the World	
	Dollars	Dollars	Percent	Dollars	Percent	Dollars	Percent	Dollars	Percent
1950	37.1	14.2	38.2	22.9	61.8	15.6	41.9	21.6	58.1
1953	46.6	16.5	35.5	30.1	64.5	18.5	39.7	28.1	60.3
1958	61.0	16.7	27.3	44.3	72.7	18.5	30.4	42.4	69.6
1963	66.6	16.8	25.3	49.8	74.7	19.4	29.1	47.2	70.9
1968	77.4	18.5	23.9	58.9	76.1	21.6	27.9	55.8	72.1

[1] Asbestos, Bauxite, Borates, Chromite, Coal, Copper, Diamond, Fluorspar, Gold, Iron, Kaolin, Lead, Magnesite, Manganese, Mercury, Molybdenum, Natural Gas, Natural Gas Liquids, Nickel, Petroleum, Phosphates, Platinum, Potash, Salt, Silver, Sulfur, Talc, Tin, Tungsten, Uranium, Zinc

THE ENVIRONMENT AND RECYCLING

The conflicts between materials availability and environmental quality can occur in two areas:

(1) Acquisition of Materials

(2) Waste Disposal

The first of these pertains to where and how natural resources are to be obtained. Conflicts between economic and materials needs and values on the one hand and environmental quality on the other, often arise in the determination of what purpose the land, water or air shall serve. And if this decision process is faulty, the environment, industry and the public can suffer. Examples of environmental concerns are where and how timber is to be cut, where strip mining shall be allowed, and where gravel pits shall be developed.

Waste disposal can result in three forms of pollution: (1) air, (2) water, and (3) solid waste. Waste can occur at any point in the materials cycle. For example, when coal is extracted from the earth, it creates solid waste. Later, when the coal is burned by an industrial plant, sulfur oxides are emitted into the air. When gasoline is used to propel a vehicle, its unmodified combustion adds pollutants, such as hydrocarbon and carbon monoxide, to the air. The final disposal of municipal waste creates air pollution and solid waste. Likewise, as materials are extracted, processed, consumed, and discarded, the environment can be degraded.

The growing technology and affluence of the American society has increased the amount of solid waste generated per person per day. Waste collection in urban areas of the United States has increased from 2.75 pounds per person per day in 1920 to 5 pounds in 1970. The character of the waste has also changed to one containing increasing amounts of non-biodegradable materials. The total solid waste produced in the United States in 1969 is shown in the accompanying table.

	Million tons
Residential, commercial and institutional waste	250
Collected, (190).	
Uncollected, (60).	
Industrial waste	110
Mineral waste	1,700
Agricultural waste	2,280
Total	4,340

Source: "Environmental Quality," The First Annual Report of the Council on Environmental Quality, August 1970.

Secondary processing, i.e., recycling of materials after end-use and reclamation of waste prior to end-use, plays a major role in attaining both goals of enhancing environmental quality and conserving materials for more effective utilization of our natural resources. Therefore, the Commission has drawn up a list of key materials for intensive study of ways to improve and increase their recycling. The metals are iron and steel and their major alloying elements chromium and nickel, and the nonferrous metals aluminum, copper, lead, magnesium, zinc, and precious metals. Key nonmetallic materials are glass, oil, paper, plastics, rubber and textiles. Municipal and industrial waste as well as certain consumer wastes, such as junked automobiles, will receive special attention.

In the commodity summaries, Appendix A, the current status in recycling and recovery of these key materials is discussed. Also, covered are the present and future environmental problems, including land use and waste disposal, that will require study by the Commission.

MATERIALS ISSUES AND PROBLEMS

In order to carry out its assignment of developing a national policy that will assure adequate materials supplies without seriously impairing the environment, many complex problems and issues must be defined and studied. It is not possible to set down a complete list of them at this time. However, from discussions with the various interest sectors, referred to earlier, a selection of what are thought to be the most important materials issues was compiled. They are given below. Other important issues growing out of economic, social and future world conditions that affect materials demand and use will be treated as the Commission's work progresses.

Domestic Materials Resources

a. How effective is our national policy to foster and encourage private enterprise in the orderly and economic development of domestic mineral and energy resources and reserves?

b. What conditions, including other national goals, exist which tend to discourage resource exploration and development? How can those apparent conflicts be reconciled?

c. Is it in our national interest for domestic industry to continue to import raw materials, at increasing rates? Should the government encourage and support the production of higher-cost domestic materials?

d. To what extent should higher-cost domestic industries be supported in the name of national defense? Which industries?

e. How can we best coordinate our efforts to preserve and improve the quality of our environment in an atmosphere supportive to exploration, investment, research, and technological development in the production and usage of materials?

f. To what extent are the growing real costs of materials the results of: declining grades of reserves, insufficient investment in technology, or rising capital and other costs? To what extent are the rising costs the result of continuing increases in construction and production labor costs without commensurate increases in productivity? What national policies and programs are needed to stimulate improvements in labor productivity?

Foreign Materials Sources

a. To what extent should imports be encouraged? For which materials?

b. How can the need to import raw materials be reconciled with the national concern with the deteriorating balance of trade?

c. What mechanisms are available or can be developed to improve the reliability of our access to necessary foreign supplies?

d. How can the security of United States investments in foreign supply sources be improved?

e. What laws, regulations, antitrust restrictions, and other governmental practices tend to place American firms at competitive disadvantages vis-a-vis their foreign counterparts?

f. How significant are foreign cartels, subsidies, tariffs, nontariff trade barriers, and other foreign practices?

g. Conversely, what domestic practices exist which tend to give domestic industry comparative advantages?

Recycling

What are the impediments and incentives to an expanded role for recycling in our materials system:

a. What programs are needed to encourage the development of more efficient market, distribution, collection and sorting systems?

b. To what extent are transportation rate structures deterrents?

c. What can State and local authorities do to encourage the development of recycling?

d. What taxes, zoning, licensing, legislation, and other governmental activities tend to impede recycling?

e. How can we facilitate the development of new products and markets for recycled materials, and does government have a role?

f. How can the concept of recyclibility be built into the total product system from design through use and disposal?

g. Should Federal procurement policies and specifications be revised to provide incentives for recovering and utilizing solid waste materials?

h. What Federal policies and what initiatives in the private sector are needed to stimulate progressive and effective economic and technology-oriented research and development programs?

i. What Federal and other programs are needed to make the American consumer understand the economic significance of recycling and its relationship to environmental control and prudent resource management?

Federal Stockpile

What role should the federal stockpile of strategic and critical materials play in the materials supply picture:

a. Should the stockpile be used to stabilize or moderate the wide fluctuations in the materials market?

b. If our stockpiles should not be used as a market regulator, how can disposals and acquisitions be handled with a minimum of market disruption?

c. To what extent is the lack of clearly enunciated disposal plans a disruptive factor?

Research and Technology

a. To what extent should Government foster applied research and development programs in materials?

b. Are the present levels of activity and types of programs appropriate?

c. What types of incentives are needed to increase and redirect R & D programs?

d. What are the relationships between materials technologies here and abroad? Are we falling behind? Where are the problem areas?

e. What role should Government play in stimulating domestic investment in new technologies? What are the obstacles to capital investment? What Government programs and incentives are needed to overcome these obstacles?

Manpower

What manpower problems confront the materials industries as related to:

a. Shortage of underground miners?

b. Skill problems?

c. Technical education?

d. Roles of Government, organized labor, and management in training activities?

Government agencies

a. What conflicting policies and programs of different arms and agencies of Government tend to be offsetting or counterproductive to a national materials policy?

b. How can these be more clearly defined and administered?

It is hoped that the above list will serve as the basis for debate and discussion, and that interested groups and individuals will transmit their views to the Commission.

APPENDIX A

Commodity Summaries

APPENDIX A—CONTENTS

IRON

Supply and demand.—The total demand for iron (contained iron) is made up of iron in ore, net imports of steel mill products, and purchased scrap, excluding scrap recirculated in the plant. In 1970, 117 million tons of iron were consumed to produce 91 million tons of steel mill products, and 17 million tons of iron and steel castings.

In this study a 2.1 percent annual growth rate for iron demand is projected. It is assumed that the demand for iron in relation to finished products will decline somewhat with anticipated improvements in steelmaking technology, such as continuous casting, and with growing efficiency in steel use, such as high-strength low alloy steel to replace ordinary steel.

Growing imports of finished steel and steel containing products lessen the domestic demand for primary and secondary iron. Competition for steel markets by other materials, such as aluminum, plastics, and concrete also may diminish the demand. Conservation of iron in consumer and industrial products through better surface protection, improved wear and attrition characteristics, more skillful product design and longer usable life may each contribute to a lower iron demand.

Domestic ore supplies about 65 percent of the primary demand for iron with the balance largely supplied by Canada and Venezuela. About 80 percent of domestic iron ore comes from the Lake Superior district largely from lower grade taconites concentrated to a high quality pellet and used almost entirely for the production of pig iron or hot metal.

In 1950 domestic ore, containing 55 million tons of iron, represented about 40 percent of world production. By 1970 the domestic production of 60 million tons of iron was less than 13 percent of world production. Over the same time period imports of iron ore have increased from 9 percent to almost 40 percent of domestic demand for primary iron.

Purchased scrap for steel production supplies about 30 percent of the iron demand. Purchased scrap has been more than needed and as much as 10 million tons were exported in 1970.

Technological advances in the steel industry are constantly changing the yield of steel from raw materials and affecting the proportions of scrap and ore consumed. These trends are reflected in the projections.

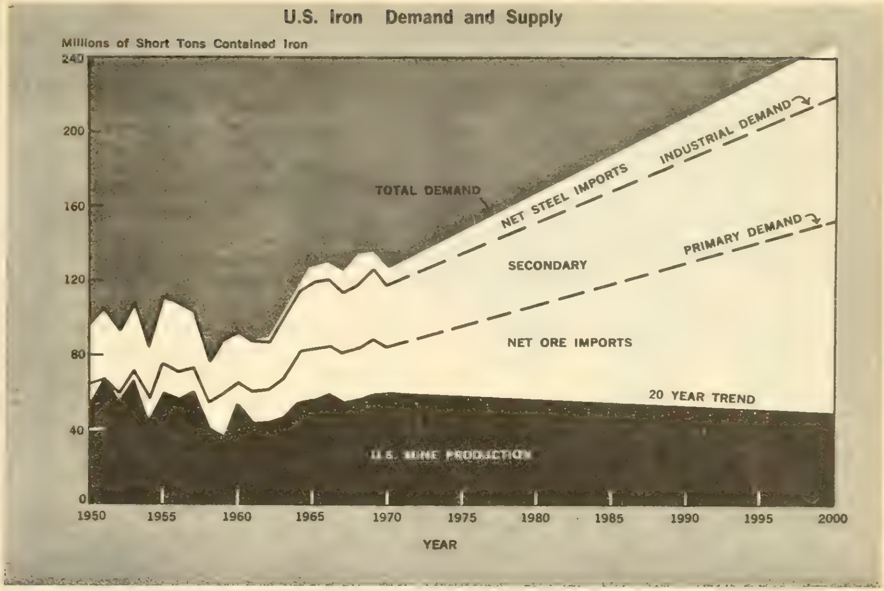
Reserves.—Domestic reserves of iron ore have been estimated at 2 billion short tons of contained iron, with an additional 16 billion tons of higher cost potential reserves. These reserves consist mainly of low-grade ores of the taconite type.

World reserves of iron ore are more than adequate through the balance of the century reflecting new discoveries and improved technology. These reserves are dispersed throughout the world, with major concentrations in Canada, Brazil, Australia, and Russia.

Recovery and recycling.—The iron recovered from the scrap generated in iron and steel production and in consuming plants is of high order, because it is clean and easily segregated from other metals. Obsolete scrap, available from waste and discard, presents the most difficult problems of iron recovery and recycling. Obsolete scrap from structures and heavy equipment may be recovered easily and sometimes can be reused rather than recycled.

Environment.—Environmental problems associated with the production of iron, from the mining of ore to recovery from scrap, are ubiquitous, pervasive, and massive in size. The tonnage of iron moving in the economy is 10 times the tonnage of all other base metals combined. The annual production of almost 60 million tons of iron in ore, requiring the mining or removal of 380 million tons of material creates problems in land use, waste disposal, restoration of the landscape, and transportation of ore to the point of use.

Discarded iron and steel products, such as used cars, tin cans, and household appliances, pose environmental problems. Scrap processing plants have air and noise pollution as well as esthetic problems. Air, water, and waste disposal problems beset the entire process of iron and steelmaking from ore to shipped steel products. Air pollution problems are associated with blast furnace, coke plant and steel melting operations, and captive power plants. Water problems arise from the discharge of large volumes of cooling water and from the disposal of waste products, such as spent liquors and used oil. Solid waste problems include disposal of mine overburden, concentrate tailings, sludges, slags, and dust from air pollution control devices.



CHROMIUM

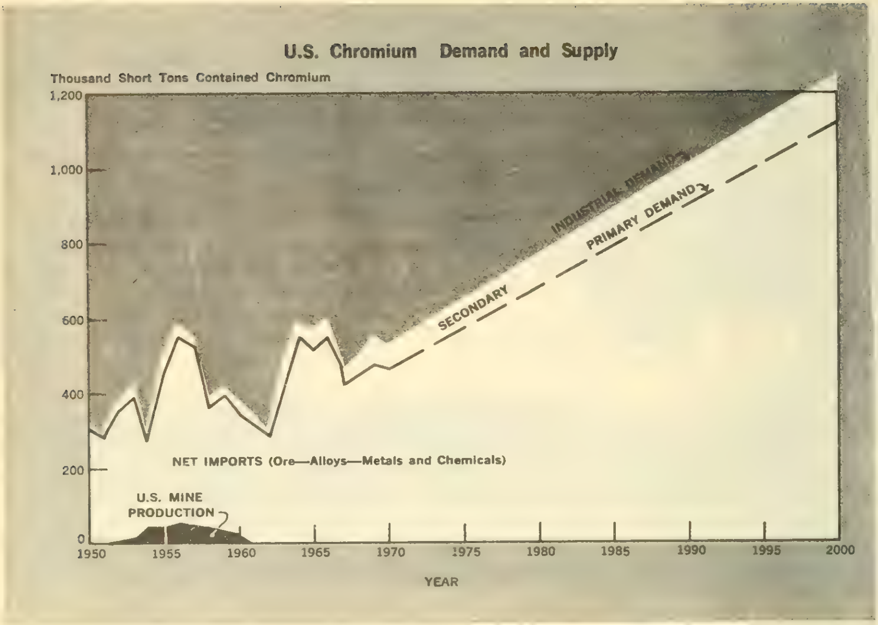
Supply and demand.—The major consumer of primary chromium is the metallurgical industry (65 percent) followed by the refractory and chemical industries. In the metallurgical industry, the production of stainless steel accounts for nearly 70 percent of the overall demand, including secondary chromium largely recycled in stainless production.

Growth in total demand for chromium to the year 2000 has been projected at 2.9 percent per year, with metallurgical uses at 3.8 percent per year, chemical uses at 2.4 percent and refractory uses declining. Anticipated advances in steelmaking will increase the recovery and conservation of chromium in the melt cycle, lessen the demand for low carbon ferrochromes, and increase the demand for high carbon ferrochromes made from lower grade ores.

There are few, if any, alternate elements for chromium in many of its uses at comparable costs, particularly where corrosion or oxidation resistance is needed over a wide range of temperatures. Chromium, along with other alloying elements used primarily to enhance strength in steel, may be conserved to some extent by more extensive heat treatment or the use of special hardening agents such as boron. The use of chromium oxide for refractories is expected to continue declining as open hearth steelmaking is phased out in favor of the BOF and electric furnaces.

All of the U.S. supply of chrome ore is obtained from offshore sources including Russia, Republic of South Africa, Turkey, and, before the U.N. sanctions, Rhodesia. Domestic production of chrome ore ceased in 1961 and present outlook is dim for any future production. Imports of chrome ore in 1970 totaled 1.4 million short tons. Russia supplied 33.5 percent and Republic of South Africa, 29 percent. Russia supplied 62 percent of our high grade metallurgical ore in 1970 because of the restrictions on Rhodesian ore.

Chromium ferroalloys, chromium metal and chemicals are all items of import and affect domestic production from ore. Chromium ferroalloys imported from Finland and the Republic of South Africa were produced from local ores, but ferroalloy imports from the other countries of West Europe and Japan were produced from imported ores.



Technological changes in stainless steel production will permit the greater use of high-carbon ferrochromes of lower chromium content, thus moderating the demand for high grade metallurgical ore and allowing greater use of the more extensive, lower grade South African ores. Countries with large chrome ore deposits, such as Republic of South Africa, Turkey, and Rhodesia, are rapidly expanding their ferrochromium production capabilities and can be expected to favor exports of ferroalloy over chrome ore.

Present government stockpiles of chromium consisting of ore, ferroalloy and metal are in excess of national stockpile objectives and the excess subject to disposition.

Reserves.—Domestic sources have never been of suitable quality to supply chromium economically. The only large known deposit is the Stillwater complex in Montana. World reserves of chromium are very large and are predominately in the Republic of South Africa and Rhodesia.

Recovery and recycling.—Stainless steel scrap is the only sizeable source of secondary chromium largely in the form of revert and prompt industrial scrap. Obsolete stainless scrap is difficult to collect, classify and clean. Stainless steel scrap containing nickel, and nickel and cobalt base alloys containing chromium, are amenable to high chromium recovery because of the other high value elements recovered concurrently.

Chromium contained in some alloy steels, in chrome plated products, and in hard surfaced products, is largely not recoverable with present technology. Some chromium does reappear as a residual in steel made from appreciable amounts of purchased scrap. Most chromium refractories are destroyed in use, and what remains is discarded as solid waste. Chemical uses are largely for pigments and dyes as well as plating and are not recoverable.

Environment.—The processing of chrome ore to a ferrochrome product generates objectionable emissions, which now are largely collected to meet air pollution standards. However, the collected dust is a solid waste disposal problem as is the slag generated during smelting. Refractory

and chemical uses of chrome ore cause solid waste disposal problems in the form of burned out refractories and iron sludge.

COBALT

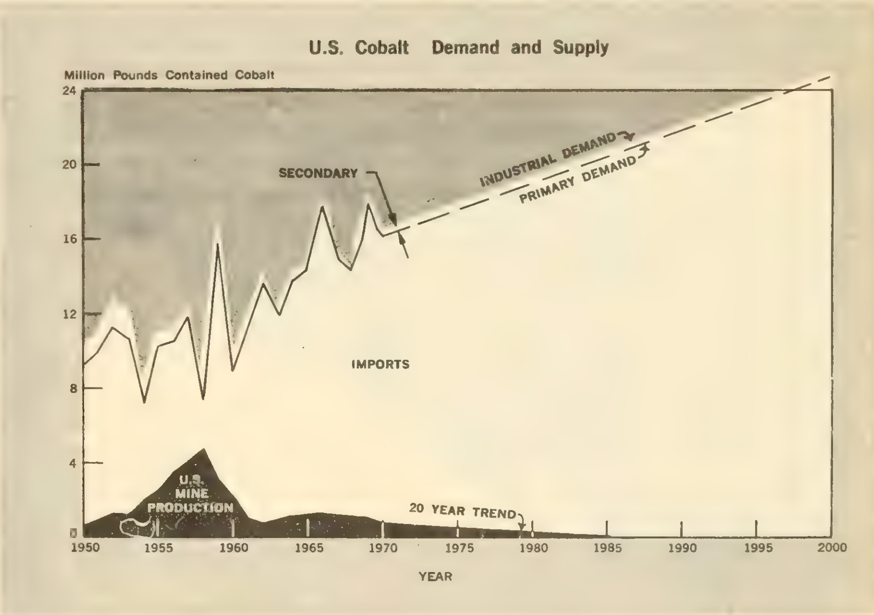
Supply and demand.—The major uses for cobalt are in the production of super-alloys, permanent magnets, cemented tungsten carbide tools and in various chemical processes. Growth in demand to 2000 is estimated at a rate of 1.5 percent per year with the greatest growth projected for uses in industrial chemical products and processes. Cobalt is used in electroplating to replace nickel only when nickel is unavailable.

Domestic production of cobalt depends on the recovery of pyrite from cobalt-bearing iron ores mined at Cornwall, Pa. World supplies of cobalt are largely produced as byproduct from ores of copper and nickel. The major U.S. source is the Congo. It is expected that some future supplies will come from lateritic deposits operated primarily for nickel. Government stockpiles now total about 77 million pounds, about double the stockpile objective.

Reserves.—At present prices, domestic reserves are small and depend on iron ore production. At higher prices, domestic resources may total as much as 270 million pounds. World reserves at present prices are mainly in the Congo, New Caledonia, Zambia, Cuba, and Canada.

Recovery and recycling.—Some cobalt is recovered from scrap occurring as revert or prompt industrial. The major portion of cobalt-bearing scrap, however, is exported to Germany and Japan where the cobalt is profitably recovered in processes not attractive in the United States.

Environment.—No known problems exist in the United States.



COLUMBIUM

Supply and demand.—Approximately 90 percent of columbium demand is in the production of high strength low alloy steels, stainless steels, and superalloys including nickel and cobalt base materials. The use in high strength low alloy steels and certain carbon steels is the largest and fastest growing application, with the use in superalloys second in growth rate. Overall demand growth is projected at 4.5 peicent per year, but future technological development could favor a greater growth. To a certain degree columbium and vanadium are interchangeable in high strength low alloy steels and titanium may replace columbium in stainless steels. In super-alloys columbium cannot generally be replaced at will. Domestic production of columbium has never been large. It ceased entirely in 1960, and today all of our requirements are imported from Brazil, Canada and Nigeria. Although most of the foreign supply is now ore concentrates, it is more than likely that future imports will be processed material such as ferrocolumbium or columbium metal. Government stockpiles are large with most of the inventory scheduled for disposal to bring the level down to about 1.2 million pounds (3 months' supply).

Reserves.—Large low-grade deposits are located in the Western States, but present technology and prices put them in the category of potential reserves. World reserves, estimated at present prices to be nearly 13 billion pounds are more than sufficient for projected world demand to the year 2000. These reserves are located principally in Brazil, Canada, and Russia.

Recovery and recycling.—Columbium in superalloys, other special alloys, and metal is recoverable and recycled to some extent. When associated with other elements in scrap such as nickel, however, the columbium content is sometimes lost if such scrap is used for making steels of lower alloy content. In high strength low alloy steels columbium is generally under 0.10 percent and not recoverable because such steels are not separated from carbon steels during recovery or recycling.

Environment.—Problems existing in connection with the possible mining of columbium ores involve open pit mining.

MANGANESE

Supply and demand.—Approximately 90 percent of the total manganese demand arises from its use in iron and steel products. Industrial chemicals, aluminum, and dry cell battery production account for most of the balance. The demand for manganese in pounds per unit of iron and steel production has been, and probably will be, fairly constant in the foreseeable future. Accordingly, future demand for manganese will parallel steel production. There seems little possibility in the near term for replacing manganese with any other material in its primary use in steelmaking.

Of our manganese needs, 95 percent is supplied from overseas sources either as ore or as usable ferroalloys and metal. The principal ore sources are Brazil and Gabon (Africa), which account for over 60 percent of our needs. Ferromanganese obtained from the Republic of South Africa and India is made from local ores, but ferromanganese from France, West Germany, and other countries is produced from imported ores.

Currently, domestic manganese production, almost entirely obtained from manganiferous iron ores out of Minnesota, is used primarily in the blast furnace to obtain desired manganese levels in pig iron or hot metal.

Government inventory of manganese is over 5 million tons of contained manganese as ore and ferroalloy representing about a 4-year supply.

High quality, low cost manganese ores are available in substantial quantities from the rest of the world. However, these sources involve transportation problems due to long sealanes and political problems in certain resource rich countries.

Reserves.—Reserves of manganese ore in the United States are almost nonexistent at present or projected world ore prices. It is estimated that manganese may be recovered from various low-grade domestic deposits at about five times the current prices for imported ore. Worldwide reserves have been estimated at 3.8 billion tons plus potential reserves of 15 billion tons. World reserves are sufficient to meet the cumulative demand worldwide for the rest of the century based on world steel production of about 2 billion tons in the year 2000. Nodules from the ocean floors may be a possible future source of manganese.

Recovery and recycling.—The manganese content in most iron and steel products is well under 1 percent. It is returned to the steel cycle in scrap, but is largely lost during the melting-refining phases of steel production.

Environment.—Since little or no mining for manganese is done in the United States, environmental problems are largely confined to processing imported ore to ferroalloy and these are minor.

NICKEL

Supply and demand.—In imparting resistance to corrosion and improving mechanical and higher temperature properties, nickel is an essential element in an increasingly technological society. It is used primarily in imparting these qualities to other metals particularly iron for the production of stainless steel. Pure nickel and nickel-base alloys are the next largest use, followed by electroplating, alloy steels, and superalloys. The iron and steel industry consumes over 50 percent of the total supply including nickel from purchased scrap.

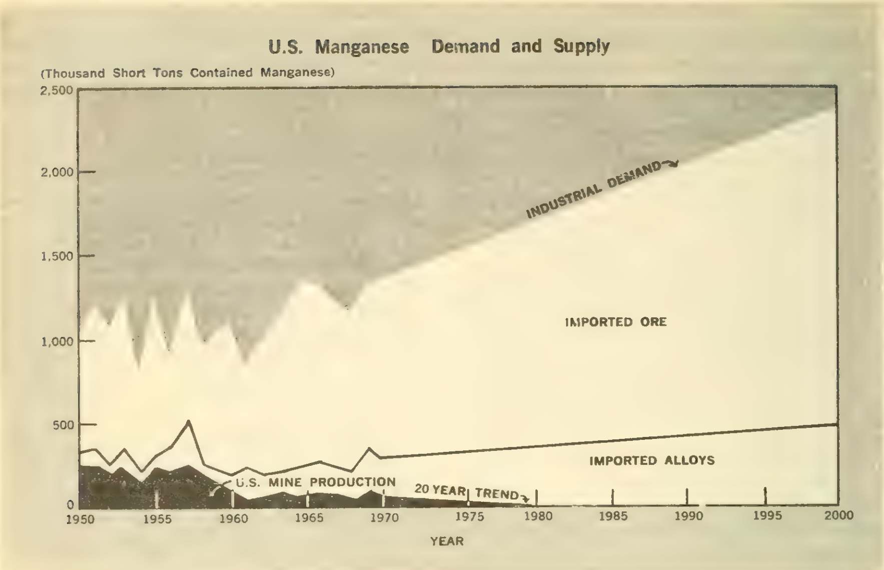
Technological changes in stainless steel production may retard the demand for nickel somewhat in favor of manganese substitution for nickel and the greater use of nickel-free stainless steels. In other uses nickel has little substitutability by other elements except possibly cobalt in electroplating.

Currently, only Hanna Mining Co. produces primary nickel in the United States. Some additional amounts are produced as byproduct at copper refineries. Our major supplier of nickel is Canada, which in 1970 produced almost 45 percent of the world supply.

Because of rising world demand, lower grade deposits are being mined and developed in many areas of the world, most notably New Caledonia, the Philippines, Indonesia and the Dominican Republic. Currently, about 70 percent of the primary nickel imported is electrolytic but ferronickel imports from lateritic sources are increasing.

At the end of 1971, approximately 52 thousand tons of nickel was reported in the government stockpile. However, the present national stockpile objective is zero.

Reserves.—Sources of nickel are widespread, particularly in the form of laterites containing as little as 0.6 percent nickel. The known world reserves at current prices are estimated at over 46 million tons of contained nickel. Domestic known reserves at current prices are estimated at 200 thousand tons but would increase to over 5 million tons at prices about 50 percent higher than current levels.



Recovery and recycling.—Nickel in many of its applications has a high degree of recyclability, particularly from stainless steels, and various nonferrous nickel alloys. In the main, these materials are returned for remelting into the same or similar products. In other nickel uses, such as electroplated products, many alloy steels and cast iron products, the low nickel content makes recovery per se technically difficult and uneconomical. However, much of this nickel reappears as an adventitious residual in common steel and iron.

Major problems are associated with the separation of high nickel alloy scrap from other materials and sophisticated techniques have been developed to separate, clean, and classify these speciality metals.

Environment.—The only serious pollution problem is caused by the emission of sulphur dioxide during the smelting of nickel sulphide ores. This problem is primarily in Canada and seems under control. Open pit mining of laterites so far has been in tropical areas where the scars heal rapidly or in remote areas.

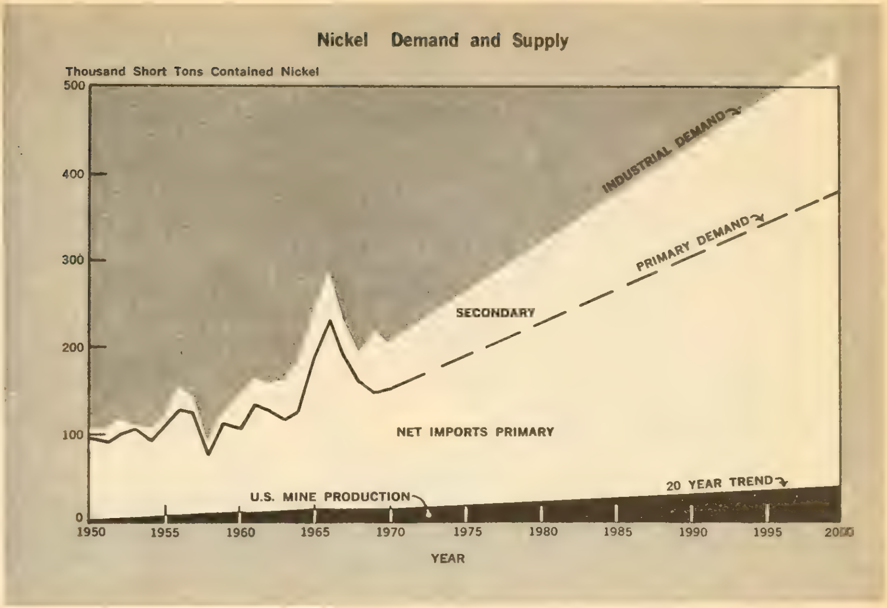
TUNGSTEN

Supply and demand.—Industrial demand for tungsten is projected to grow at about 5 percent per year because of its unique properties, its use in tungsten carbide, and the present lack of suitable substitutes in many applications.

Supply.—During the middle fifties the domestic output of tungsten exceeded our needs. In the last 5 years, government stockpile inventories have been reduced and some of the excess has been exported to Japan, Europe, and the Communist bloc countries. Today 129 million pounds are in government inventory with 69 million of it considered in excess of objective.

Almost the entire domestic supply of tungsten comes from one mine at Pine Creek, Calif., and from coproduct production of molybdenum at Climax, Colo. Imports are at a low level with the future level dependent upon world prices and demand and the possibility of sales by China.

Reserves.—Domestic reserves at current prices are estimated at 175 million pounds or approximately a 10-year supply. Overseas reserves are concentrated in China plus smaller deposits in Korea and South America.



Recovery and recycling.—The recovery and recycling of tungsten from its ultimate end uses varies from high in carbide cutting tools to very low in light bulbs and tire studs. Reported data on secondary recovery are estimated and are probably low.

Environment.—Environment problems associated with tungsten mining are local in character and primarily are concerned with disposal of tailings from mining and water purification from solvent extraction plants.

VANADIUM

Supply and demand.—The use of vanadium as an alloying element in iron and steel products accounts for 75 percent of vanadium demand. Vanadium is used also in titanium alloys and chemical products. Growth in demand is projected at 5 percent per year based on the increasing demand for high strength, low alloy steels.

Supply.—Over the last 20 years most of our domestic vanadium was obtained as a coproduct in the mining of uranium from the Colorado Plateau. As a result, during the fifties and early sixties, vanadium in excess of demand was stockpiled by the government or exported by industry. Currently, reduced domestic production from the Colorado Plateau is augmented by output from Arkansas (the only mine operated for vanadium alone), from ferrophosphorous production, and from various vanadium residues, slags, and spent catalysts. Imports of vanadiferous slags from Republic of South Africa have become an important source in the last 3 years.

Although vanadium concentrates, oxides, chemicals, and ferroalloy have been items of U.S. export, the current world supply picture favors imports. Imports of vanadium bearing slags are principally from Republic of South Africa, Russia, and until recently, Chile. Ferrovanadium is imported from Europe.

Domestic vanadium production is difficult to project, as it is affected by world prices, ore quality, demand for uranium, and availability of slags, residues, fly ash, and spent catalysts. Increased environmental controls will increase

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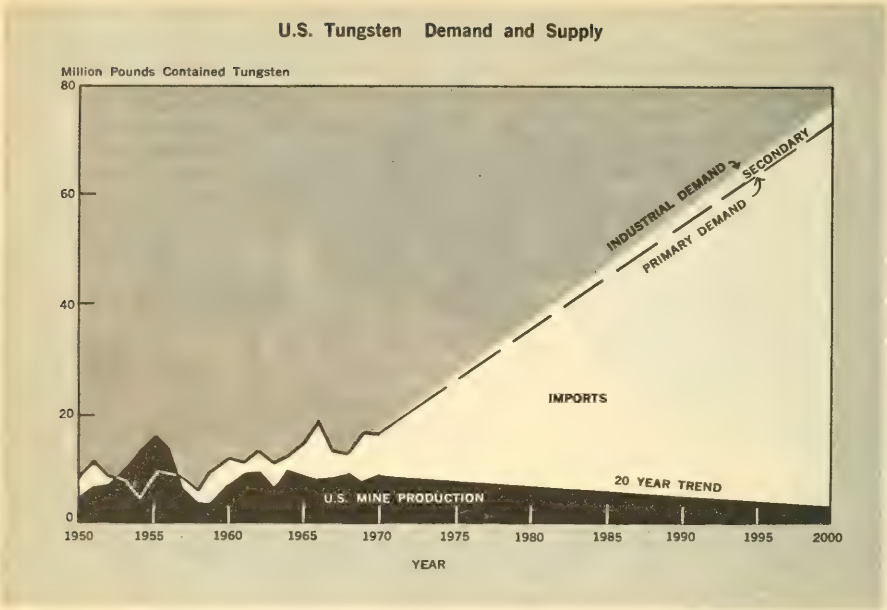


the availability of vanadium from many energy fuels in the form of petroleum refinery residues, boiler residues and fly ash. Government stockpiles of vanadium are considerably more than the objective of 540 short tons of contained vanadium (about 1 month's supply), and the excess is scheduled for disposal.

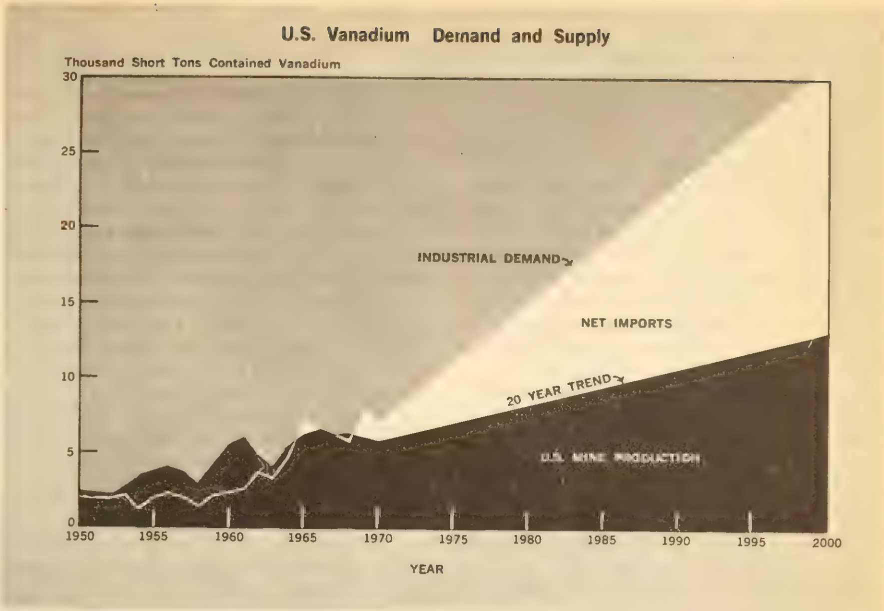
With the exception of molybdenum, possible alternates for vanadium, such as columbium, chromium, or nickel, are of foreign origin to a greater extent than vanadium.

Reserves.—Domestic reserves of vanadium at current prices have been estimated at 115 thousand tons of contained vanadium with additional resources estimated at about 3.5 million tons at higher prices. Rest of the world reserves are estimated at 10 million tons at recent price levels plus an estimated 5 million tons additional at higher prices. Major overseas reserves are located in Russia, Republic of South Africa, and Australia. Vanadium residuals in tar sands, crude oils and phosphate shales represent an additional resource and are a growing source of supply.

Recovery and recycling.—Most of the vanadium used in steel production is lost because the vanadium content in most steels is under 0.5 percent and such steels usually are not separated from carbon steels in recycling. Tool steels and some structural alloy steels are recycled to obtain a satisfactory recovery of the vanadium and other associated alloy elements.

Titanium alloy scrap lends itself to good vanadium recovery to the extent that the scrap is used to produce new titanium of similar vanadium content. In some chemical processes vanadium used as a catalyst is recovered and reprocessed to new material.

Environment.—Vanadium, mined by both open pit or underground methods, presents some problems in land use and disposal of solid waste. Vanadium, as a coproduct with uranium production, is subject to environmental problems originating with the uranium. Production of various vanadium products from ore or their subsequent use in metal or chemical production cause no particular environmental problems.



ALUMINUM

Supply and demand.—Over the past two decades domestic mine output of aluminum has ranged from 344,000 to 583,000 short tons per year, contained aluminum. Mine output reached a record high in 1970. World bauxite production, which in 1970 was 12.5 million short tons (aluminum equivalent) has increased during the two decades approximately 10 percent per year. The U.S. share of world production from primary sources was less than 5 percent in 1970.

World output of aluminum metal in 1970 continued its rapid growth, which in recent years has averaged about 9 percent per year. Although the United States was the largest producer, accounting for 4 million short tons, or 37 percent of the world total, it supplied only 14 percent of its aluminum requirements from domestic sources. The U.S.S.R. was the second largest world producer with 11 percent, followed by Canada, Japan, Norway, and France in that order.

World demand increased slightly during the year, but the United States demand for primary and secondary dropped below that in 1969, and was about one-third of estimated total world use. Demand has continued to lag behind output and 15 percent of this capital intensive industry was shut down bv the end of 1971.

Imports in 1970 accounted for about 89 percent of the U.S. supply of bauxite and alumina. This ore as in previous years came mainly from the Caribbean area and Northeastern South America. Other major importers of bauxite were U.S.S.R., from Greece, Hungary, and Yugoslavia; Japan, from Indonesia, Malaysia, and Australia; and West Germany from Greece, Yugoslavia, and Australia.

The trend toward converting bauxite to alumina in countries of origin and exporting alumina to aluminum producing countries continued. U.S. imports of alumina, largely from Australia, Jamaica and Surinam, increased 34 percent in 1970 reaching 1.4 million short tons of contained aluminum. Another major importer of alumina was Norway, from United States, Canada, and Jamaica.

The U.S. industrial demand for aluminum in the year 2000 is expected to be between 18.8 and 36.6

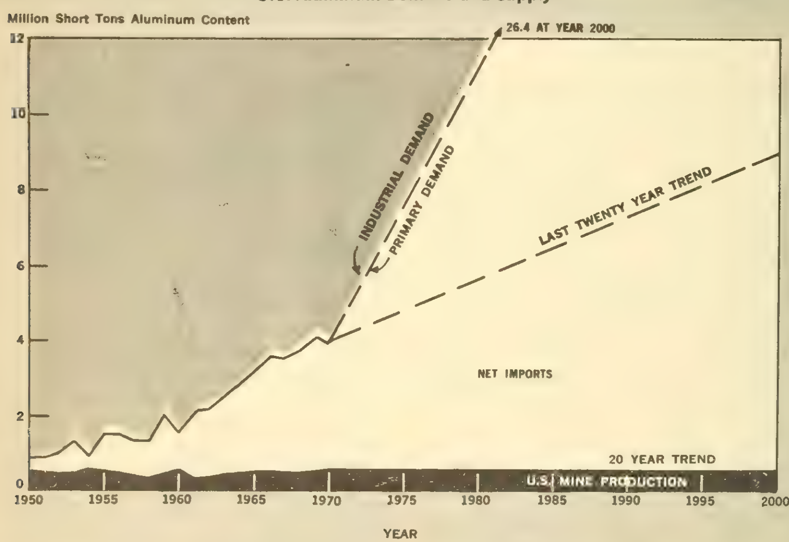
million short tons. Recent developments in aluminum technology foreshadow increased use of aluminum in automobiles and in the building and construction industry. Moreover, the price differential between aluminum and copper for electrical applications, favors the use of aluminum as an electrical conductor. An analysis of these and other contingencies indicate that the probable U.S. industrial demand for aluminum in 1985 will be 12.2 million short tons, representing an average annual growth rate of 7.2 percent compared with an average of about 7.4 percent during the past decade. The growth rate is expected to decrease to less than 6 percent per year toward the end of the century, averaging 6.6 percent per year for the period 1970 to 2000 and reaching 28.4 million short tons in year 2000.

Future aluminum demand in other industrialized countries is assumed to parallel the growth in the United States. Growth in less-developed countries in Africa, Asia, and South America is expected to be considerably higher than in industrialized countries. Accordingly, overall demand growth in the rest of the world is expected to be somewhat greater than in the United States. In the year 2000 it is expected to range between 34.5 and 67.3 million short tons. As in the United States probable demand is set on the high side at 52.9 million short tons. Parallel to the United States, rest-of-world aluminum demand during the 1970–1985 period will grow more rapidly than in the 1985 to 2000 period. Probable demand in the rest of the world in 1985 is 22.3 million short tons.

It is assumed that under conditions of increasing prices, as well as improved technology, domestic mining can be continued at about 500,000 short tons per year through the year 2000. This is an equivalent supply of about 15 million short tons of aluminum. Consequently, the United States will have to continue to rely on massive imports for almost all of its aluminum supply.

Reserves.—Domestic known reserves of bauxite, from which aluminum is being produced, are in Arkansas and total about 44 million long tons (13 million long tons contained aluminum). An additional reserve of 1 million long tons of bauxite (0.3 million long tons contained aluminum) in

U.S. Aluminum Demand and Supply



Alabama and Georgia is being mined for specialty uses.

The potential resources of bauxite in the United States, other than the present reserves, are chiefly in: (1) large low-grade bauxite clay deposits and deeply buried and thin bauxite deposits in Arkansas, Alabama and Georgia; (2) ferruginous bauxite deposits in Oregon and Washington; and (3) deposits of low-grade ferruginous bauxite in soils and weathered basalts in Kauai and Maui, Hawaii. Commercial recovery of aluminum from these potential bauxite resources awaits development of improved mining and processing technology, an increase in aluminum price, or a combination of both of these factors.

The world reserve of bauxite at the 1970 average price level of 28.7 cents per pound of aluminum is 2.5 billion short tons (aluminum content). The potential world supply level of aluminum is virtually unlimited at a metal price of about 37 cents per pound.

Recovery and recycling.—The relative portion of aluminum recovered from old scrap is small and has been steadily declining during the past two decades, dropping from 8 percent of the U.S. industrial demand in 1951 to 4 percent in 1970. Of the total amount of aluminum scrap (new and old) theoretically available for recycling, 48 percent was recycled in 1969, according to a recent study.

The producers of primary metal purchased about one-third of the 1 million short tons of aluminum scrap, both old and new (prompt industrial), that entered commerce in 1970. An unknown but significant quantity of aluminum scrap was generated during the year but was used by the companies that generated it (run around scrap).

The availability of new aluminum scrap is a direct function of current primary production, semifabricating and fabricating operations. Such scrap may reenter the flow of supply many times in one year and, hence, is not an appropriate component of supply although that portion of new scrap, which is used outside of the aluminum industry, creates demand for aluminum from primary sources. Except for some forms of aluminum cans and packaging, old aluminum scrap is normally recovered long after it has passed through the aluminum production cycle and hence, it augments the available supply of aluminum during the year.

Environment.—The reduction of aluminum metal from its oxide is a very energy-intensive process and accompanied by all environmental control problems germane to electric power generation. Additional problems can be created by fluorine-containing dust and gases emitted from alumina reduction cells. The disposal of waste red muds from present-day Bayer plants treating bauxite poses a problem that will become more critical with time. However, land use conflicts also would accompany any large-scale employment of domestic clays as a primary source of aluminum.

BERYLLIUM

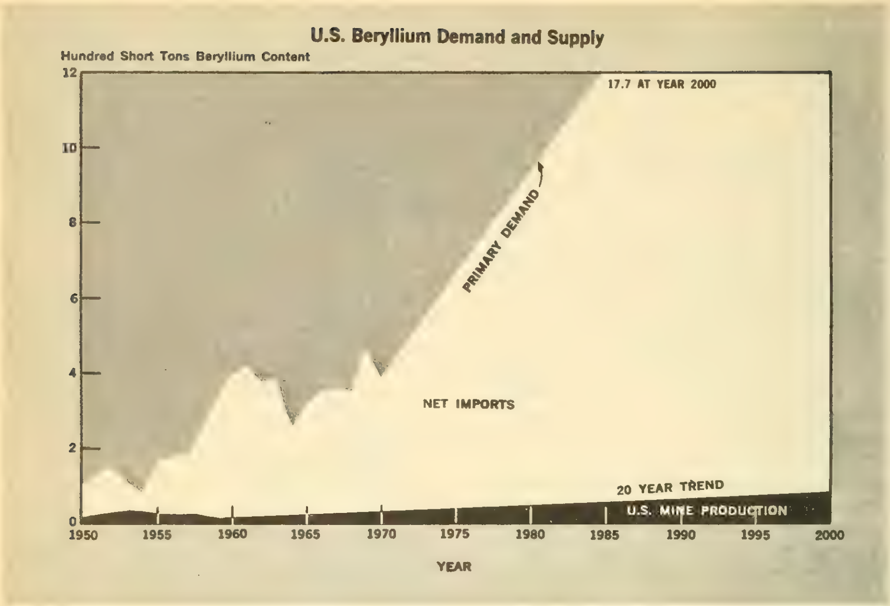
Supply and demand.—The historic source of most of the beryllium for the U.S. has been hand sorted beryl imported mainly from South America, Africa, and India. The known reserves of beryl are not very large, so the discovery, and implementation in 1969, of a process to beneficiate low-grade bertrandite ores was an important development.

Production of beryllium ore from a new mine at a bertrandite deposit in Utah contributed 98 percent of the total U.S. mine output in 1970. This plus minor beryl production from other States, equalled about 50 percent of the rest-of-the-world production. Domestic consumption of beryllium dropped as sales and Government programs were cut back.

Fourteen countries produce beryl outside of the United States. Of these, Brazil, the U.S.S.R., India, and Argentina are major producers. Japan and France continue to rely on foreign sources for their beryl ore. Beryl ore was imported by the United States in 1970 chiefly from Brazil, Uganda, the Republic of South Africa, and Argentina. Twenty short tons of beryllium powder, alloys, and wrought products were exported in 1970.

U.S. industrial demand for beryllium in the year 2000 is expected to be between 1,200 and 2,160 short tons. The probable level of demand within this range is set at 1,790 short tons representing an annual growth rate of 5.3 percent. These data were derived by estimating future consumption in various end uses. The expected beryllium demand in the rest of the world is seen to increase faster than in the United States, reaching 1,030 short tons for the year 2000.

Mining of the large, disseminated low-grade deposit of bertrandite in Utah will minimize the inefficient mining of pegmatites, and will supplement the normal supply of foreign ore, not supplant it. A 5.5 percent annual growth rate in domestic mine production appears feasible. This



would not satisfy the domestic cumulative probable demand of 26,500 short tons to the year 2000. However, by opening one or two more mines on similar known deposits the domestic supply could be doubled or tripled.

Rest-of-world beryl production, continued at the 1970 rate to year 2000, would supply 10,000 short tons of contained beryllium. It is assumed that deposits of other beryllium ores, such as those deposits found in Labrador and Mexico, will be able to supply an additional 10,000 short tons at the 1970 beryllium price of $60 per pound. This 20,000 short tons is ample supply for the rest-of-world cumulative probable demand of 12,500 short tons for the 1970–2000 period.

Increased productivity resulting from nonberyl mining and beneficiation is expected to hold prices for ore at present levels through year 2000. The United States has large stocks of beryl, beryllium-copper master alloy, and beryllium metal for national emergencies.

Reserves.—Reserves of pegmatitic beryl ores recoverable at certain price levels are extremely difficult to appraise because of the geologic discontinuity of pegmatites. In the United States, small reserves of beryl are known in New England, South Dakota, and Colorado. Much larger deposits, with beryl crystals too small for hand sorting are found in Utah, Colorado, New Mexico, and Nevada. These deposits, which are amenable to drilling, sampling and analysis, are relatively continuous ore bodies with an approximate size and average mineral value known. At $60 per pound, the amount of beryllium ore available from deposits now being mined is 28,300 short tons beryllium content for the U.S. and 391,700 short tons for the rest-of-world. Estimates of the amount of beryllium that could be recovered from other deposits if the price for the metal reached $80 and $100 per pound are 39,100 and 80,100 short tons for the United States, and 544,900 and 1,138,100 short tons for the rest-of-world, respectively.

Recovery and recycling.—Recovery of beryllium from secondary sources has been insignificant in the past and is not expected to play a major role in the supply picture during the next 30 years. Only 20 short tons of old beryllium scrap are

expected to be recycled in 2000—slightly more than 1 percent of the expected U.S. industrial demand in 2000.

Environment.—The high toxicity of beryllium complicates machining techniques and end use applications. However, since the toxicity problems have been recognized and methods of control initiated, beryllium can be recovered, purified, and fabricated without danger to the careful worker and the environment.

COPPER

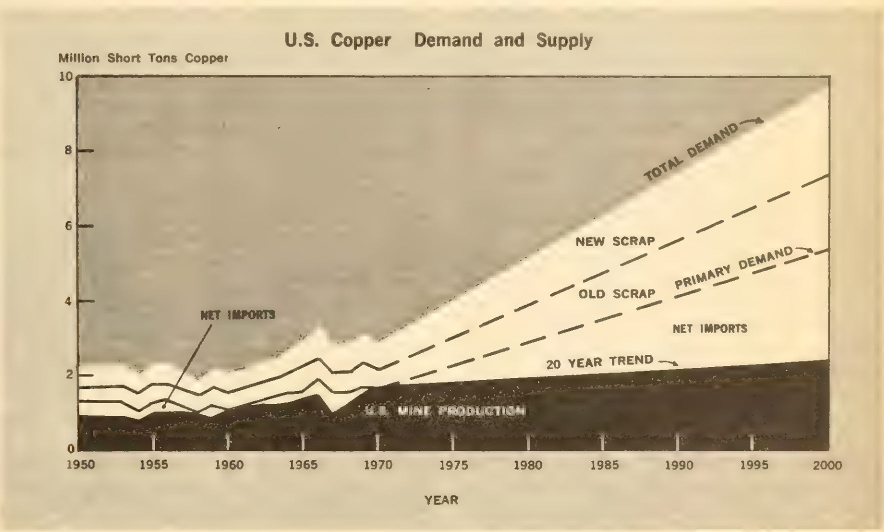
Supply and demand.—During the 1951 to 1970 period world mine production of copper increased by 126 percent. U.S. output registered an 85 percent growth. Domestic consumption followed closely the production trend with industrial demand for the 1950–71 period increasing 26 percent for refined copper and 29 percent including all secondary consumption (old scrap).

The recent expansion of domestic mine productive capacity has not been matched by increased smelter capacity. The delay in expansion of smelter facilities appears to be largely linked to uncertainties surrounding smelter stack gas pollution standards to be established by States, and determination of the proper technology to meet the anticipated requirements. Enforcement of existing standards has caused some curtailment in use of present smelter capacity and has resulted in a significant increase in exports of copper concentrate beginning in June 1970.

The components of domestic total demand in 1970 for copper were approximately 54 percent from mine output, 5 percent from imports, 26 percent from new scrap and 18 percent from old scrap (the apparent surplus reflecting changes in inventory and Government stockpiles).

U.S. industrial demand for copper in year 2000 is estimated to range between 5.5 and 11.3 million short tons (primary demand and old scrap). The most probable demand within the range is estimated at 7.1 million tons representing a growth rate of 4.2 percent during the period 1970 to 2000 (9.68 million short tons including new scrap). Demand for copper in the rest of the world is projected to range from a low of 16.8 million tons to a high of 34.9 million tons in year 2000, corresponding to annual growth rates of 3.2 and 5.8 percent, respectively. The most probable copper demand in 2000 for the rest of the world is estimated at 24.4 million tons.

Reserves.—Domestic known reserves of copper in ore, based largely on the Bureau of Mines 1964 survey, are estimated to be 81 million tons at the average 1970 price. Arizona, Montana, Utah, New



Mexico, and Michigan were the leading States in measured and indicated reserves, with Michigan having the largest inferred reserves. The five States accounted for over 90 percent of the total reserves, 95 percent of which are in copper ores and the remainder in mixed or complex base metal ores. Tenor of the copper ores is estimated to average 0.86 percent copper.

Known reserves of copper in the rest of the world are estimated to be 259 million tons at 1970 prices. The leading producing countries of Chile, the U.S.S.R., Zambia, Peru, Zaire, and Canada account for 73 percent of this total. Remaining reserves are divided among many other countries including Australia, China, Finland, Iran, Japan, Mexico, the Philippines, Poland, Republic of South Africa, Sweden, and Yugoslavia.

A large in-use resource of copper in the form of scrap has accumulated and is growing in the highly industrialized countries. The copper-in-use-pool resource has been estimated to be 40 million tons for the United States, 40 million tons for Europe, and 10 million tons for all other countries.

Recovery and recycling.—Except for a few dissipative uses, much of the copper used adds to a "reserve" that is ultimately recoverable. At present, this "old copper scrap" supplies about a fifth of domestic demand for refined copper. A recent study showed that in 1969 only 61 percent of the old scrap, theoretically available for recycling, was actually recovered. From any standpoint—conservation, supply, or economics—improvements in the salvaging and processing systems for recovering and recycling secondary copper (and its coproducts) merit immediate and intensive investigation.

Environment.—Emission of sulfur compounds to the atmosphere during smelting is the most pressing immediate problem facing the domestic copper industry. New technology and large capital investments will be required to either modify existing pyrometallurgical practices or adopt new chemical-process techniques as a solution to the problem if the United States is to maintain a viable copper industry. The domestic extraction industry also faces potentially critical land-use conflicts. Unless opposing views on surface restoration standards, waste disposal, and pollution issues are reconciled without excessive increases in operating costs, the competitive position of the U.S. supplies will deteriorate sharply. The Wilderness program and public works designed to conserve essential land and water resources will increase confrontations with the industry and will present increasingly difficult problems for reconciliation.

Because approximately one ton of makeup water is required per ton of ore processed in the concentrator, and with population increases and industry expansions, conflicts for sufficient water to process increasing quantities of ore can be anticipated in the Western States where much of the production is obtained. Decreased water requirements could result from research on the beneficiation step.

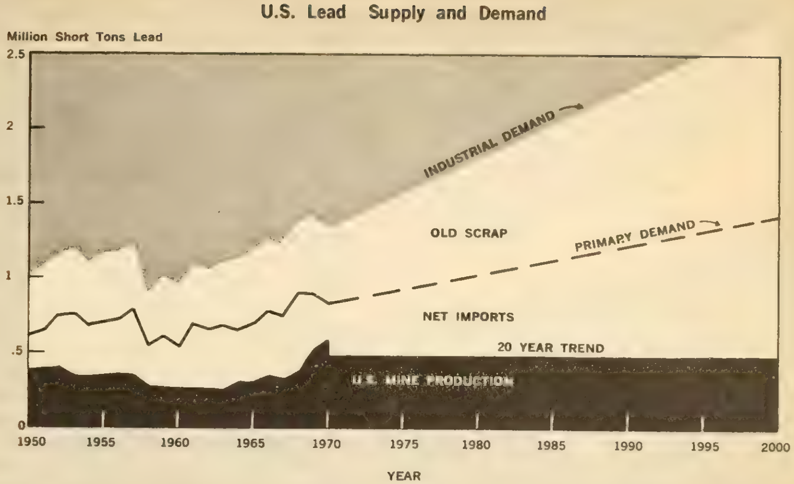
LEAD

Supply and demand.—World mine and smelter production of lead has been in an upward trend during the past two decades in response to a rising demand. Mine output increased from 1.9 million short tons of lead in 1951 to 3.8 million short tons in 1970, and expansion of smelting-refining capacity throughout the world continued to exert an international competition for mine output of lead in concentrates. In 1969 the strong demand resulted in a worldwide depletion of refined lead stocks and rising prices throughout the free world. However, in 1970 the market underwent a sharp reversal from the strong demand and shortage of supply that persisted through 1969 and into the first half of 1970.

Expansion of mine production added over 1 million tons of lead in concentrates to the annual world supply in the last decade. The largest increase was in the United States, which reached a total production of 572,000 short tons in 1970, and which is now the leading world producer. Of the 38 countries with recorded smelter output, 11 countries exceeded 100,000 tons in 1970. In addition to the expanding supply of new lead, an increasing output of secondary lead was indicated in the industrial areas as battery scrap increased in volume. The secondary industry in the United States, demonstrating a 2.7 percent average annual growth over the last decade, reached a record 516,000 tons from old scrap in 1969, then declined slightly in 1970.

Import of lead materials has contributed substantially to the U.S. supply of concentrates for smelting, bullion for refining, and refined metal for consumption. In 1970, as a result of increased domestic supply, the foreign component was reduced to less than 27 percent.

During recent years, the available supply of lead has exceeded U.S. industrial demand, result-



ing in a substantial buildup in stocks. The 4.1 percent average annual growth in demand since 1965 has been due primarily to the increase in transportation requirements for gasoline additives and batteries. In contrast to this increase, the tonnage for many historical end uses, such as construction, printing, and communications, has been relatively stable.

The U.S. industrial demand for lead in year 2000 is expected to range between 1.67 and 3.54 million short tons with a probable demand of 2.7 million tons, representing a 2.4 percent average annual growth. The rest-of-the-world demand in year 2000 is expected to range between 5.68 and 7.08 million tons, with a probable demand of 6.9 million tons, representing a 2 percent average annual growth. The probable demand for primary lead in the United States in year 2000 is estimated at 1.4 million tons with a substantial increase in recycled secondary lead to 1.3 million tons.

The domestic mine capacity has been expanded by new plants and expansion of other mines in Missouri. The domestic resource base has been increased significantly by exploration and ore delineation in Missouri and, also, by deep exploration in Idaho and other Rocky Mountain States. The average grade of ore mined mainly for lead in 1960 was 2.14 percent. The average grade mined in 1970 was 4.80 percent, thus indicating the improved lead content of the new Missouri ore developments.

Accordingly, it is likely that under normal operating conditions and indicated lead demand, the domestic mines can continue to operate at 600,000 tons of metal annually and that reserves and output can be increased as demand warrants.

The secondary supply component is expected to continue the 2.7 percent growth of the past decade to approximately double the 1970 output as battery scrap increases in availability.

Reserves.—The estimated known world reserves of lead in ore are 103 million tons of which North America accounts for over 52 percent. The known reserves are well distributed with presently economical ore exploited in 48 countries of the world. In general, the Western European industrial countries are deficient, as is Japan, in minable reserves to meet smelter and consumer demand and are thus dependent on reserves developed in Africa, South America, Canada, and Australia. Major developments in these areas have established reserves substantially above current depletion.

Recovery and recycling.—Lead, because of its relative inertness in metallic form, is seldom lost and is valuable enough so that industry has always sought to recover it. Consequently, its recycling

record is rather good. About 38 percent of the U.S. industrial demand in 1970 was supplied from old scrap. However, according to Battelle-Columbus estimates, 821,000 short tons—or almost 60 percent of the lead theoretically available for recycling in 1969—was not recycled. The Battelle estimate includes lead as T.E.L. in gasolines and lead chemicals. Disregarding these hard-to-recover lead components, almost 60 percent of the lead available for recycling was recovered in 1969. Recycling of scrap is expected to continue its important role as a supply component. By the year 2000, almost one half of the U.S. supply is expected to come from secondary sources.

Environment.—The lead industry is faced with environmental control problems in air, water, and land use. Part of the solution of these problems will have to come from developing improved and new technology.

MAGNESIUM

Supply and demand.—Over the past decade, annual domestic production of primary magnesium, as metal and contained in compounds, has increased about 4 percent to 1.15 million short tons in 1970. In the rest of the world, annual corresponding production of magnesium has increased about 67 percent during the past 10 years and reached 5.1 million short tons in 1970. The U.S.S.R., Czechoslovakia, Austria, and North Korea were major producers of magnesite in 1970.

World production of magnesium metal in 1970 totaled 243,300 short tons, with the U.S. production representing about 46 percent of the world total. The U.S.S.R. was the second largest world producer with 23 percent, followed by Norway, Japan, and Canada.

United States imports of magnesium in compounds of 84,000 tons in 1970, as in previous years, were primarily from Greece, India, and Yugoslavia. The U.S. exported 34,000 tons of metal mostly to West Germany, and continued to be a net exporter of metal.

World demand for magnesium compounds in 1970 was 5.4 million tons of contained magnesium, and the U.S. demand was an estimated 20 percent of the total world use. World metal demand was 219 thousand tons; U.S. metal demand for primary and secondary (from old scrap) was 7 percent lower than 1969, and was about one-half of the estimated world demand.

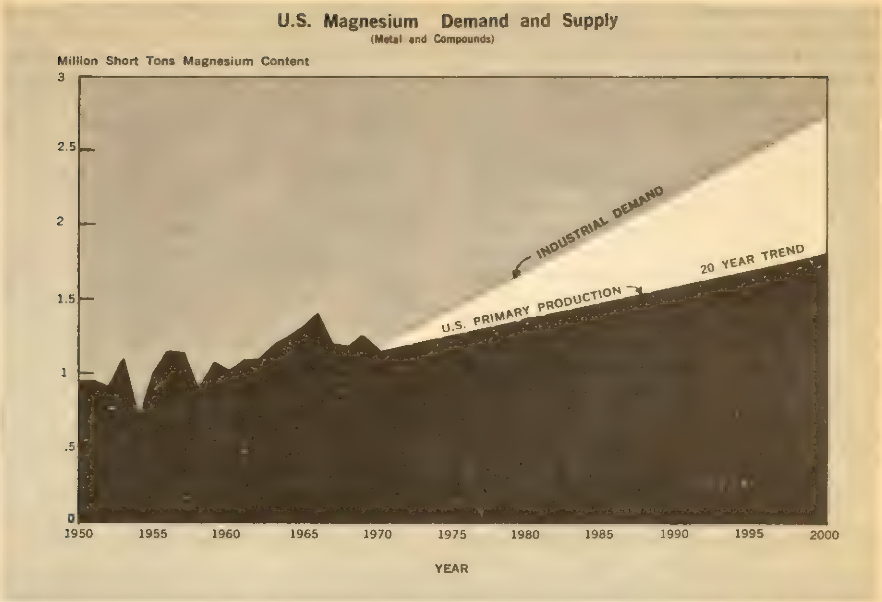
The U.S. primary demand for nonmetal uses of magnesium in year 2000 is expected to range between 1.3 and 2.4 million short tons. Domestic demand for magnesium metal is estimated to range between 0.3 and 0.7 million short tons in the year 2000. The probable U.S. total demand for magnesium in year 2000 will be 2.8 million short tons, near the high side of the estimated range. Principal factors contributing to the high estimate include the anticipated growth in the iron and steel industry, and increased use of magnesium in transportation equipment and in a wide variety of industrial and consumer products.

Magnesium demand in the rest of the world in the year 2000 is expected to range between 5.7 and 9.5 million tons. The probable demand, 8.5 million tons, is set near the high side of the estimated range. Anticipated future technological shifts in use patterns toward magnesium metal in place of other materials and the use of magnesium refractories in steelmaking facilities in industrialized and developing countries are major reasons for this high growth rate in magnesium demand.

Reserves.—Sea water, well and lake brines, and dolomite, the sources of most of the world's magnesium, are available in unlimited quantities in nearly all countries. Sea water with a magnesium content of 0.13 weight-percent may be considered an inexhaustible resource. Reserves of magnesium salts obtained as brines from underground evaporite deposits are difficult to estimate. Moreover, available information on magnesium salts in surface evaporites is insufficient to estimate reserves. The Great Salt Lake contains an estimated 630 million tons of magnesium chloride.

Large deposits of dolomitic limestone and dolomite are widely distributed throughout the United States and the rest of the world. Other principal magnesium ores are olivine, brucite, and magnesite. The known domestic reserves of olivine are estimated around 300 million tons, averaging 48 percent magnesia, and are located in North Carolina, Georgia, and Washington. Known domestic brucite reserves are estimated to total 3 million tons in Nevada and Arizona. Brucite also is found in the United Kingdom, Ireland, and Canada. Reserves in North Korea are estimated to be 2 million tons.

Large deposits of magnesite occur in the Peoples Republic of China, North Korea, Australia, and the U.S.S.R. Deposits with less than 100,000 tons of contained magnesium occur in India, Czechoslovakia, Austria, the United States, and other countries.



In the U.S., 88 percent of the magnesite reserves occurs in Nevada, 11 percent in Washington, and 1 percent in California. Other magnesite occurs widely in various States but the reserves have not been delineated.

Recovery and recycling.—Recovery of magnesium from old scrap has been modest in the past amounting to only 3 percent of the 1970 U.S. primary demand for metal. No dramatic change is anticipated for the coming decades. For the year 2000, the amount of old scrap recycled is estimated to be 30,000 short tons, or 5 percent of an estimated U.S. primary demand for metal of 580,000 short tons.

Environment.—Dolomite resources normally can be quarried without interfering with other land use. Sites for sea water magnesia plants must be selected carefully so that they do not conflict with shore property for private and public use. Also, topography, wind and ocean currents, and quality of sea water must be considered in locating plants. Effluent from sea water plants has not been considered to be deleterious to the sea environment.

Certain forms of magnesium metal, such as turnings, dust, and scrap react with water to evolve hydrogen, which may lead to spontaneous explosion; hence, scrap magnesium is stored and shipped in a moisture-free environment.

MERCURY

Supply and demand.—In 1970, world mine production of mercury decreased to 284,000 flasks from an all-time high of 290,000 flasks in 1969. Spain and Italy continued as the major producers, contributing about 32 percent of the total new supply. Canada continued to be a significant producer, increasing its output to 24,400 flasks from 21,200 flasks in 1969. In addition, Ireland and Czechoslovakia each produced over 1,000 flasks by virtue of byproduct mercury from base-metal refining.

World demand decreased to an estimated 295,000 flasks in 1970. The largest mercury consuming countries including France, Germany, Japan, the United Kingdom, and the United States, continued to rely on foreign sources for a substantial part of their supply. United States mines accounted for about 41 percent of the total

U.S. supply including secondary. Imports of 21,672 flasks remained a major component of domestic supply, contributing about 33 percent. Changes in industry stocks provided about 14 percent; the remainder about 12 percent, came from secondary sources, including Government releases of surplus metal. Stocks of AEC surplus mercury to be sold by GSA totaled 13,491 flasks.

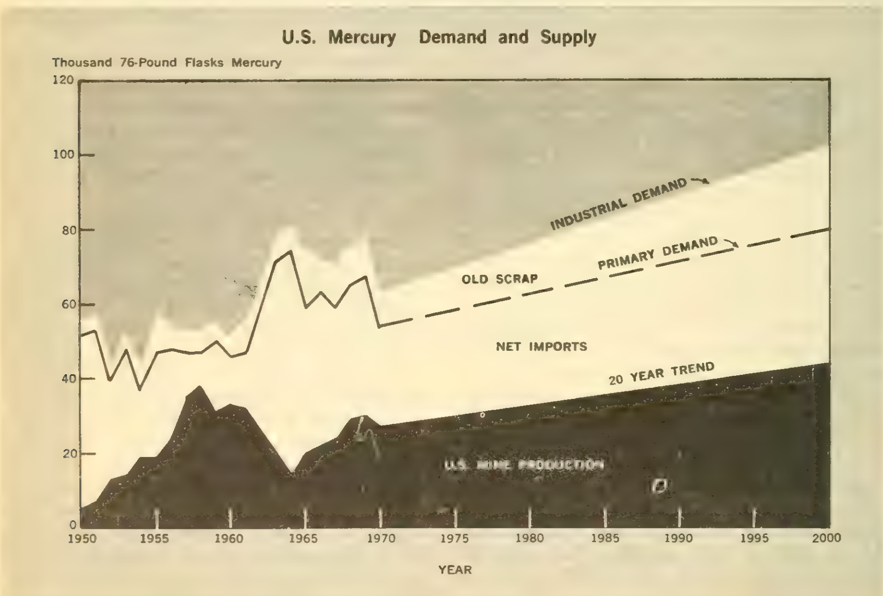
U.S. industrial demand of mercury in the year 2000 is expected to range between 92,000 and 176,000 flasks. This represents annual growth rates of 1.4 to 3.6 percent during 1970 to 2000. The most probable demand within the range is estimated at 102,000 flasks.

For the rest-of-the-world, end-use data are not available but the uses of mercury are similar to those in the United States. The estimated range shows a low demand of 295,000 flasks and a high of 478,000 flasks in year 2000. This represents annual growth rates of 0.8 to 2.4 percent during 1970 to 2000. The most probable demand is estimated at 386,000 flasks.

The United States will continue to rely on foreign sources, such as Spain, Italy, and Mexico, for a large part of its supply. Canada is expected to provide an exportable surplus to the United States. Turkey will also become a major supplier.

Reserves.—Updating 1962 data, provided by the U.S. Geological Survey, with estimated reserve figures available in 1970 gives the following assessment of known mercury reserves for the United States, at a constant 1970 price per 76-pound flask of $360 and $750, recoverable reserves amount to 380,000 and 935,000 flasks, respectively, and for the rest of the world to 4,900,000 and 14,065,000 flasks.

Recovery and recycling.—During the past two decades, secondary recovery of mercury has increased steadily from 3.6 percent of U.S. industrial demand in 1951 to a peak level of 20 percent in 1965. In the future, secondary sources should become an increasingly important component of mercury supply. Pressures will continue to mount to recover mercury from industrial processes to prevent environmental contamination. Mercury will be recovered from waste effluents from caustic soda and chlorine, and plastics plants, and also from discarded mercury-containing mechanical and electrical devices.



Environment.—The major loss of mercury during extraction occurs in the stack gases, with minor losses in the calcine, soot, and spillage. Furnace plants are equipped with dust-collection units so air pollution from particulates is not a major problem. The small quantity of dust is either discarded or processed to recover the contained mercury.

Poisoning of workers caused by exposure to mercury may occur in mining and retorting metallic mercury and in any industry in which mercury is used. Therefore, precautions such as proper ventilation, use of respirators or masks, personal cleanliness, use of mercury vapor detectors are required.

Much of the mercury consumed is for dissipative uses which may ultimately lead to environmental pollution. Spent catalysts, in the form of inorganic mercury compounds from plastic manufacturing, can contaminate natural waters. Mercury losses from mercury cells in the caustic soda and chlorine industries contribute to air and water pollution. Other uses of mercury giving rise to environmental concern are in agriculture, amalgamation, paints and pulp and paper.

In March 1971, mercury was designated a hazardous air pollutant by the Environmental Protection Agency. According to the Clean Air Act of 1970, emission standards will now be promulgated for mercury.

PLATINUM

Supply and demand.—Domestic platinum production and refining moved erratically during the past two decades, while rest-of-world production increased more steadily. U.S. primary demand for platinum peaked in 1966, reflecting highs that year in chemical, glassware, electrical equipment, and jewelry uses. In 1969, platinum-group metals in the United States moved into an oversupply situation that worsened in 1970, and the first half of 1971. Prices of most group metals dropped and so did industrial consumption and toll refining. The past two decades also saw strong advances in domestic imports, exports, secondary and toll refining, and industrial demand, but widely fluctuating refinery production.

Total U.S. industrial demand for platinum in year 2000 is expected to range between 1.23 and 2.27 million troy ounces. The probable level of demand within the range is 1.3 million troy ounces, corresponding to an annual average growth rate of 3.1 percent during the next three decades. Demand in the rest of the world during the 1970–2000 period is expected to be concentrated in the industrialized countries, and the consumption pattern would differ according to the relative development of the major consuming industries. Rest-of-world demand is expected to range between 3 and 4 million troy ounces in year 2000. The probable demand within the range is set at 3.5 million troy ounces, representing a growth rate of 4.3 percent annually during 1970–2000.

Domestic reserves of the platinum-group metals are almost entirely in copper ores and are estimated at about 3 million ounces. Because the value of the domestic production of platinum-group metals is insignificant compared with the copper production, the price of platinum and other platinum-group metals has little effect on their production as byproducts.

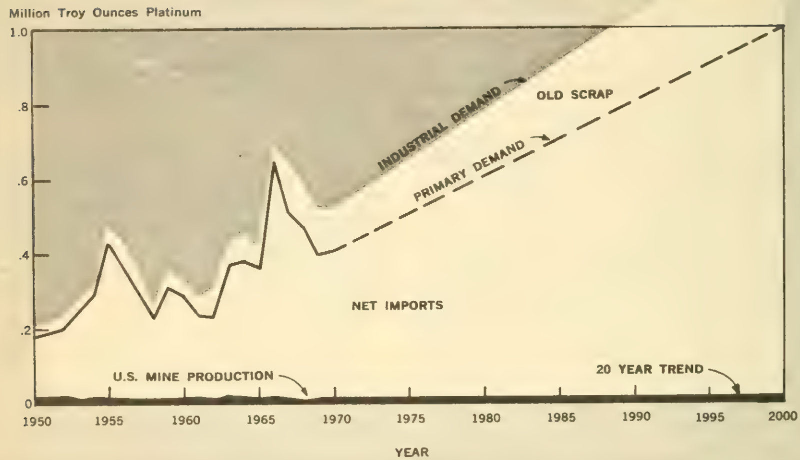
Cumulative probable domestic production of copper during the 1970–2000 period is expected to be 108 million tons. This cumulative production total is contigent on a long-term upward trend of copper prices. On this basis the availability of byproduct platinum-group metals from domestic copper sources during the next three decades will be 3.1 million ounces.

The platinum-group metals reserve in the rest of the world was estimated to be about 421 million troy ounces minable at 1970 prices. Additional world resources of platimun-group metals recoverable at higher prices are estimated to be at least 114 million troy ounces. Environmental problems associated with the production of copper are likely to have a limiting influence on the development of domestic platinum-group metals resources. However, deposits of platinum-group metals in the rest of the world usually occur in thinly populated areas and land-use problems should have little influence on their exploitation.

Reserves.—Currently recoverable reserves at \$133 and \$175 per ounce of platinum metal, are estimated for the United States at 1.3 and 1.7 million troy ounces, and for the rest of the world at 213.3 and 291.9 million troy ounces of platinum metal, respectively. Because of the byproduct nature, of most of platinum production, even very large increases in price have little effect on reserves.

U.S. reserves are almost entirely in copper ores, with a very small quantity in placers at Goodnews Bay, Alaska. The copper ores are

U.S. Platinum Demand and Supply



estimated to average about 1 ounce of platinum-group metals in 6,000 tons of ore (35 tons of recoverable copper). The placers are mostly platinum, but supply a significant amount of iridium and ruthenium to domestic refiners. The placers contain only a slight amount of palladium.

In 1969, estimates of South African reserves were increased from 60 million to 200 million troy ounces. New mines are being opened in the Merensky Reef, including one open pit mine. Producers in this area now claim to have the capability to meet any foreseeable demand, probably until the next century. Prospecting and exploration of the Great Dyke ultrabasic formation in Rhodesia has disclosed several significant occurrences of platinum-group metals which may indicate potential resources approaching 100 million ounces. "Significant quantities" of platinum have also been recently announced in New Zealand and in the nickel deposits of Australia.

Recovery and recycling.—The nondissipative uses and high-unit-value of the platinum-group metals has given rise to an elaborate, extensive, and efficient secondary recovery industry. Secondary recovery of scrap platinum-group metals increased from 82,000 ounces in 1961 to 330,000 ounces in 1970. Secondary recovery represented 12 percent of the total U.S. supply of platinum-group metals in 1970, and 25 percent of the industrial demand, though probably not all secondary refined metals were consumed in the United States.

Even larger than the quantity of secondary refined scrap is the amount of toll refined platinum-group metals. (Secondary recovery is of purchased scrap, whereas toll refining is platinum metals refined on toll and returned to the consumer.) Toll refined platinum-group metals were 700,000 ounces in 1961 and 1,722,000 ounces in 1970. In 1970, 63 percent of the toll refined material was platinum and 33 percent was palladium. Toll refining of platinum and rhodium grew steadily from 1961 to 1968, but palladium had a very low year in 1966.

Environment.—Since platinum-group metals are mostly produced as a by-product in the mining and refining of other metals such as copper, no specific environmental problems exist in the primary extraction of platinum-group metals per se.

In secondary recovery, the collection, processing, segregation, and refining of platinum-group metals require only minimal space and virtually no hazardous or offensive treatment methods. The secondary refiners are faced with tightening requirements for air and water effluent treatments but these have no specific hazards or complexities unique to the platinum-group metals.

TIN

Supply and demand.—World tin mine production increased from 169,000 long tons in 1951 to 227,000 long tons in 1970, but U.S. production remained inconsequential. Although demand for tin in the rest of the world rose about 24 percent during the last decade, U.S. demand for primary tin showed a 6 percent drop across the same period.

Malaysia, Bolivia, Thailand, and Indonesia provided 62 percent of the tin produced in the free world in 1970. Other countries in the free world having significant tin production include Australia, Zaire, and Nigeria. The U.S.S.R. and the Peoples' Republic of China also have substantial production and reserves.

Imported metal was the major component of domestic supply, comprising nearly 65 percent of the total in 1970. Secondary tin metal was the other important factor, furnishing 26 percent of the supply in 1970.

By 2000, the U.S. industrial demand for tin is expected to range between 101,000 and 140,000 long tons with a probable demand of 130,000. The pattern of demand for tin in the rest of the world is not expected to differ drastically from that in the United States during the next 30 years except that greater usage is expected for tin in tinplate for food and other containers, especially in developing countries. Such emphasis on tinplate will result in increased secondary recovery in the rest of the world, and this has been anticipated in setting the expected range for year 2000 for the rest of the world at 220,000 to 390,000 long tons. The probable demand is 310,000 long tons, representing an annual growth rate slightly less than that established for the United States.

Almost all of the approximately 2.1 million tons of primary tin which will be needed by U.S. consumers between 1970 and 2000 must be supplied by imports. The historical sources, Malaysia, Thailand, Bolivia, and the United Kingdom, are likely to continue to provide nearly all U.S. tin. Should Australia's promising production potential materialize, Australia could well become a source of U.S. supply, and might lessen the importance of Bolivia as a source of tin for the United States.

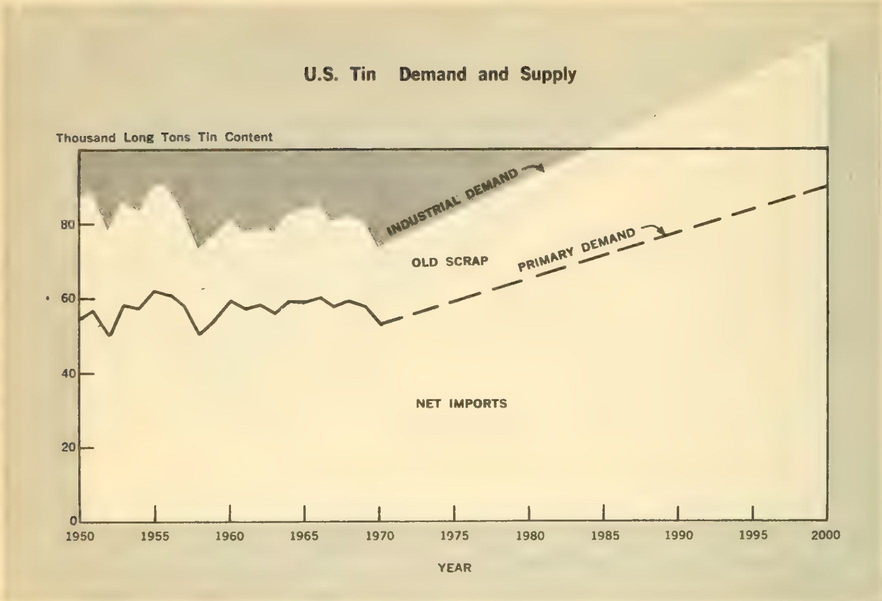
Reserves.—Measured and indicated reserves in lode and placer deposits in the United States are insignificant compared to tin reserves of the rest of the world. They occur mostly in the Western States and on the Seward Peninsula of Alaska. Tin reserves in Canada are mostly at Mount Pleasant, New Brunswick and in the properties of Cominco, Ltd.'s Sullivan Mine at Kimberly, British Columbia. Both are lode in character and are produced as byproducts of other ores—usually copper, lead, or zinc.

Mexico has minor reserves of tin, sufficient to support small scale placer and lode mining, usually in conjunction with working lead, zinc, or silver.

An assessment of currently known quantities of cassiterite (tin content which would be recoverable in the United States and in the rest of the world, at various price levels), is as follows: At $1.75 and $3 per pound of tin metal, 5,000 and 50,000 long tons of tin, respectively, for the United States, and 4.18 and 9.08 million long tons for the rest of the world.

Recovery and recycling.—Leading the world in recycling tin, United States meets approximately 27% of its demand with secondary metal. Secondary copper smelters and foundries recover 46 percent of the secondary tin from copper-base scrap in alloy ingots and castings. Other secondary smelters and refineries reclaim 41 percent of the secondary tin from lead- and tin-base scrap. Tin, as metal, is reclaimed from clean tin-base and tinplate scrap at 11 detinning plants located in 7 States. Small amounts of pig or bar tin are recovered from tinning solutions and go mostly into chemicals.

Environment.—Because 99 percent or more of the primary tin consumed by the United States reaches this country ready to use, mining and smelting pollution problems are practically nonexistent. In any secondary detinning operation, tin-containing muds are generated as waste material. Waste water from the rinsing of detinned steel may contain small amounts of caustic, sodium nitrate and tin. Drosses and dusts accumulate in industrial centers, especially on the east coast, but these eventually become sources of secondary tin and do not constitute an environmental problem during the periods of accumulation. Organotin compounds, known for over 100 years, have taken on new importance as agri-



cultural biocidal chemicals as a result of concern over mercury. Certain organotins decompose during natural weathering to nontoxic compounds.

In Southeast Asia, particularly Malaysia, restrictions are imposed against abandoning dredged ground until it has been returned to a productive capability. No restriction of supplies of tin appear likely because of these laws, but the cost of such rehabilitation might be passed along to the consumer.

TITANIUM

Supply and demand.—There has been a nearly continuous rise in world production of primary titanium during the 20-year period 1951–70, from 0.35 to 1.78 million short tons titanium content. Although domestic mine output increased about 60 percent during the two decades, the U.S. share of world titanium output declined from 97 percent in 1951 to 18 percent in 1970. However, the United States consumed over 27 percent of the world mine output of titanium in 1970. During the past two decades, the overall demand for primary titanium in the United States increased 110 percent, from 233,000 to 490,000 short tons of titanium content. Most of this increased demand was for nonmetal uses. To satisfy the shortfall between increased demand and domestic mine production, rutile imports increased sharply while ilmenite imports rose only moderately. Rutile is the basic raw material for titanium metal and the preferred source of TiO_2 for pigment produced by the chloride process.

The U.S. industrial demand for titanium in year 2000 is expected to range between 1.1 million tons and 2.6 million tons. The most probable demand within the range is estimated at 2.1 million tons representing an average annual growth rate of 5.0 percent between 1970–2000.

The expected range for the rest of the world shows a low demand of 2.2 million tons and a high of 5.0 million tons in 2000. This represents annual growth rates of 2.0 and 4.8 percent. Considering the large increase in use of titanium pigments abroad, which will develop with improvement in the standard of living, the most probable demand is 4.2 million tons, representing an annual increase of 4.2 percent during 1970–2000, a lower rate of growth than forecast for the United States.

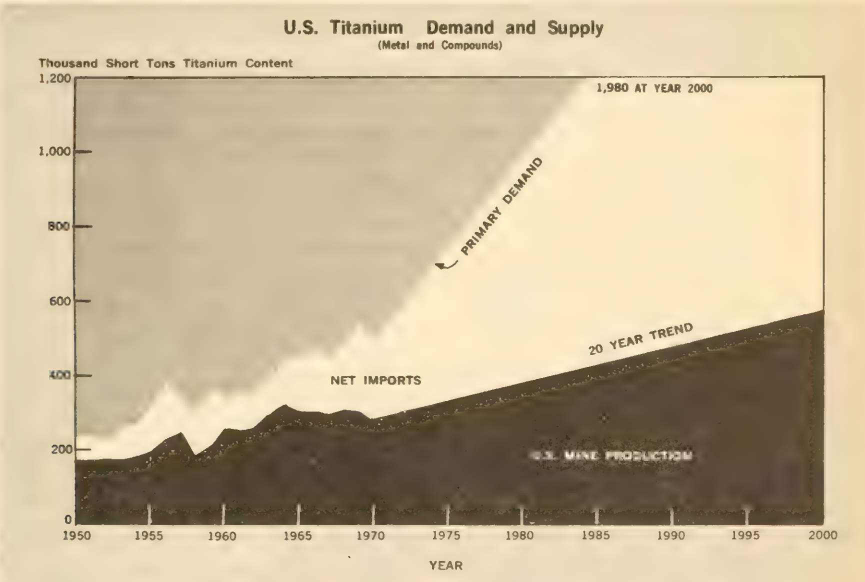
Domestic reserves of 60.4 million tons of titanium are mostly ilmenite and occur principally in New York, Wyoming, New Jersey, Florida, and other Eastern States. Most of the approximately 32-million-ton commercially workable reserves of ilmenite at the 1970 pigment price is about equally divided between rock deposits in New York and Virginia and sand deposits in Florida, New Jersey, and Georgia. The United States will continue to rely on foreign sources, such as Australia and probably Sierra Leone, for the major part of its supply of rutile.

In 1970 approximately one-half of the domestic production of titanium was mined from sand-type deposits. Although the current rate of operation could be continued at present price levels, conflicting land use and water pollution problems in mining are likely to inhibit any large-scale expansion of production from some of these deposits. Alleviation of environmental problems will tend to increase the cost of any additional domestic supplies of titanium and will probably result in a shift to the more abundant rock-type deposits as the predominant source of titanium.

Reserves.—Domestic reserves of ilmenite occur in both rock and sand deposits. About equal quantities are produced in the United States from each type. Rutile also occurs in both rock and sand deposits, although none is produced from rock-type deposits. In some countries, such as India and Ceylon, ilmenite and rutile occur in the same sand deposit and are separated as coproducts. Although occurring together in the sand deposits of Florida and Georgia, rutile and ilmenite are concentrated in a single product.

By updating previously published 1965 domestic data and 1956 world data with estimated reserve figures available in 1970, an assessment of the currently known quantity of the rutile reserves in the United States and in the rest of the world that would be available, with present technology, is as follows: At prices of \$0.45 and \$0.58 per pound titanium in pigment, for the United States 150,000 and 400,000 short tons (titanium content), respectively, and for the rest of the world 7.20 and 31.55 million short tons (titanium content).

Recovery and recycling.—In 1970, scrap metal consumption accounted for about 30 percent of the



total ingot output. Most of this scrap apparently represents in-house material generated by the primary producers of ingots and mill products. A large quantity of scrap is also generated by the consumers of titanium mill products in fabricating these to finished components. About one-third of this scrap is returned to the metal cycle. Most of the secondary material, however, consists of mixed alloys and contaminated material. About one-half of this material is consumed in other industries while the remaining half is discarded or accumulated in stocks pending development of technology which will permit its recovery.

Economical means are needed by the titanium metal industries for utilizing a larger percentage of the new titanium scrap that is being generated. Efficient means for using more of this material by the industry would reduce sponge metal requirements and, potentially, production costs. Feasible processes for collecting, sorting, and refining scrap are likely to be developed before 1980. It is thus estimated that secondary sources will become an increasingly important component of titanium metal supply. Old scrap should become available before 1980, and it is estimated that by 2000 old scrap will supply 40 percent of the requirements for titanium metal.

Environment.—Operating factors in the titanium production cycle that relate to the environment include disposal of solid and liquid wastes. Significant quantities of mud and slimes, resulting from dredging and concentrating titanium minerals from some sand deposits, constitute a serious and growing problem of disposal for some operations. The mud and slimes, which contain approximately 50 percent kaolin and considerable organic matter, are acidified and permitted to settle in large mud lakes on land which must be purchased by the mining company. The small quantity of clear water resulting from the settling must be neutralized with lime before it is fed back into nearby streams.

The principal solid waste generated at plants using the sulfate process to make titanium pigments are copperas ($FeSO_4.7H_20$) and the monohydrate ($FeSO_4.H_20$). About 1.1 million tons of byproduct copperas and 0.4 million tons of the monohydrate are generated annually at domestic plants. About one-fifth of the copperas is utilized in making iron oxide pigments, ferrites, and fertilizers, and in water treatment plants. The remainder, containing a small quantity of entrained sulfuric acid, is neutralized and dumped on land, in streams, in the ocean, or stockpiled. Apparently all of the monohydrate, containing entrained acid, is dumped in the same manner.

ZINC

Supply and demand.—World mine production of zinc rose from 2.66 million short tons in 1951 to 6.06 million short tons in 1970, representing an average annual growth rate of 5.2 percent during the past decade. Canada ranked first with 23 percent followed by the U.S.S.R., United States, Australia, Peru, Japan, and Mexico that accounted for an additional 44 percent.

In primary metal production, the United States ranked first with 16.2 percent in 1970, followed in order by Japan, U.S.S.R., Canada, Australia, Belgium, France, and West Germany accounting for 53 percent. The large mine and smelter productions of zinc in the U.S.S.R. along with that produced in Bulgaria, East Germany, Poland, North Korea, and China were respectively, 21 percent and 22 percent of the world mine and metal outputs.

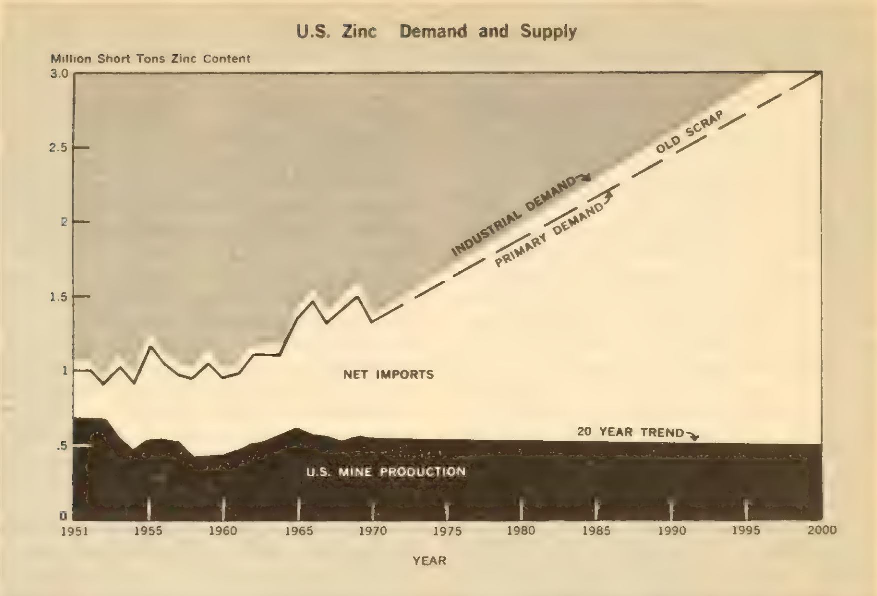
For many years the United States has been dependent on imports of foreign zinc concentrates for a large portion of its smelter production and the imports of zinc metal to meet demand. In 1970 imports of zinc in ore and as metal declined 13 percent and 17 percent, respectively, from the all-time highs established in 1969. The major suppliers of zinc in ore were: Canada, 60 percent; Mexico, 25 percent; and Peru, 9 percent. Of the imported metal, Canada furnished 45 percent; Japan, 12 percent; Peru, 12 percent and Australia, 11 percent.

The U.S. industrial demand for zinc in 2000 is expected to range between 2.12 and 4.2 million short tons with a probable demand of 3.3 million short tons representing an annual growth rate of 3.0 percent during 1970–2000.

For the rest of the world, a probable demand of 10 million short tons is expected for 2000 reflecting an annual growth rate of 2.8 percent. The range of demand in 2000 is projected to be between 6.9 million and 11.5 million short tons with the probable demand closer to the high forecast.

Domestic reserves of zinc have a wide geographic distribution and the supply from currently known sources is expected to be exhausted by the year 2000. Consequently, the current substantial U.S. dependence on imports is projected to grow.

Reserves.—Presently known U.S. zinc reserves, recoverable at current prices, are estimated to



contain 30 million short tons of zinc. This figure, down nearly 4 million short tons in the past 2 years, reflects the permanent closure of a number of mines in 1970 and 1971. The geographical distribution of the domestic reserve is 67 percent east of the Mississippi River, 17 percent in Western States and 16 percent in West Central States. World reserves outside the United States are estimated to contain some 100 million short tons.

Extensive resources, now considered inferred reserves, exist in the zinc producing areas of the United States and would undoubtedly be developed under the incentive of a growing demand accompanied by price increase. Arizona, Montana, Nevada, Washington, Illinois, and Virginia are some of the States having potential resources for developing reserves needed to supply a substantial portion of a projected growth in demand.

Recovery and recycling.—Recycled old scrap traditionally furnished between 5 and 9 percent of domestic requirements. However, recovery of secondary zinc could be improved from more old scrap items, notably die castings from worn out and obsolete appliances, industrial machinery or junked automobiles. According to a recent study, only 182,000 short tons or 14 percent of secondary zinc was recovered from a total of 1,271,000 short tons theoretically available for recycling in 1969.

Environment.—Although zinc mining is generally an underground operation and there are few objectionable surface mining or waste stripping problems, the underground waste and mill tailings represent a land-use conflict problem in some locations. Sintering and roasting plants converting zinc sulfide concentrates to zinc oxide for smelting or electrolytic refining produce sulfur dioxide and other fumes which may pose pollution problems.

FOREST PRODUCTS

Supply and demand.—Since 1950 the consumption of industrial wood products has increased by about a third and now stands at a record level of 13 billion cubic feet. If the anticipated increases in population and economic activity take place, the demand for timber products will continue to grow rapidly. Recent Forest Service projections show that by the year 2000, the total demand for industrial wood products from domes-

tic forests will be more than double the present level.

Domestic timber supplies are not likely to rise fast enough to meet the projected increases in demand. If the present relatively low level of forest management continues, rising demands for timber will exceed available supplies within a very few years. The prospective shortfall in supply is likely to be accentuated by further losses of commercial forests lands and constraints associated with the management of much of the commercial area for multiple purposes.

The most serious prospective timber supply problems in the period immediately ahead relate to softwoods used for lumber and plywood products of major concern in the housing program. The outlook for the pulp and paper industry is somewhat better than for lumber and plywood. But this industry too will have to take steps to improve its raw material supply situation by such measures as growing more timber, increased recycling, and improved technology. The prospective shortfall in timber supplies will mean increasing competition for timber and higher prices for timber products. Higher timber prices would also result in the greater use of substitutes. However, there are likely to be substantial environmental, economic, and social costs associated with the increased use of substitute materials. Timber is a renewal resource, unlike most competitive materials. Wood products are biodegradable. Wood can be processed with relatively little pollution and with relatively low energy requirements compared with most competitive materials.

GLASS CONTAINERS

Supply and demand.—Because of the importance of glass containers in the recovery and reuse of municipal waste products the glass discussion in this report is limited to containers. Glass containers are widely used in the packaging of foods, beverages, drugs, cosmetics, and other products. During the past decade, their growth averaged 5.3 percent per year in physical units. Comparable growth rates, however, are not expected to be maintained through the 1970's and beyond. Although there will be a steady growth, increasing competition from metal cans, and the possibility of widespread introduction and use of all-plastic beverage bottles and composite containers, are offsetting considerations. Aside from the beverage market, the plastic container has been the chief source of competition for the glass container, particularly in such areas as household supplies, toiletries, and medicines.

The basic raw materials used in the production of glass—silica sand, limestone, soda ash, and minor amounts of many other materials—are plentifully available domestically and are relatively low in cost. Cullet, or crushed glass, which currently represents from 5 to 15 percent of the raw material mix, is generally added to facilitate the melting process and to make the batch more workable.

Production of glass containers, therefore, does not present a serious drain on natural resources in the United States. Moreover, in the face of intensive competition from plastic and metal containers and overcapacity in the glass container industry, production is currently more than adequate to meet domestic demand.

Apparent consumption of glass containers in the United States is virtually tantamount to shipments, as exports and imports of empty glass containers account for approximately 1 percent or less, respectively of total U.S. shipments. High transportation costs generally discourage foreign trade in this commodity. Several U.S. companies are producing glass containers in large markets overseas.

Recycling and recovery.—Traditionally, crushed waste glass (cullet) has provided some 5 percent of the ingredients needed to produce new bottles and jars. The waste glass generated at individual bottle plants generally provides an adequate supply of cullet for this purpose. In line with the trend toward more utilization of cullet, the input at some plants now represents 10 to 15 percent of the total raw material batch.

Bottle redemption programs initiated by the glass container manufacturing industry in mid-1970 have augmented supplies obtained from commercial cullet dealers. Collections under this program through 1971 have totaled approximately 793 million units, with quarterly volume rising progressively. One of the industry's near-term objectives is to accumulate a sufficient number of used glass containers to meet about 30 percent of the industry's total raw material requirements. At current production levels this would require the redemption of over 11 billion glass containers annually.

Most of the reclaimed glass is used in the production of new containers. However, some has

been recycled on an experimental basis into such products as interior wall panels, terrazzo tile flooring, glass wool insulation, reflection highway paints, bricks, and "glasphalt," a new blacktop paving material containing crushed glass aggregate.

Collection rather than the reprocessing poses the greatest reclamation problem at the present time. Labor, transportation, and other costs involved in obtaining and supplying cullet to glass container manufacturers are not cost-competitive with the basic glass raw materials. In order to reduce collection costs and to provide for more effective utilization of potentially recyclable materials contained in municipal refuse, ongoing research is being sponsored by both Government and industry sources into all areas of recycling of not only glass, but of all packaging materials.

Environment.—Glass containers hold a unique position among the items appearing in litter and solid waste. Being chemically inert, glass does not leach, rust, rot, mold, or putrify, nor does it cause disease or noxious gases. Glass containers, nevertheless, are a factor in litter and municipal solid waste, accounting for about 6 percent of litter by item count and about 5 to 6 percent by weight of municipal solid waste. Glass containers create visual pollution in litter and have been singled out as a special problem because they do not degrade and consequently remain intact until picked up.

PLASTIC MATERIALS

Supply and demand.—Applications of plastics materials pervade the entire economy, from temporary packaging to appliance components to relatively permanent construction uses. In 1970, production of plastics materials was more than 19 million pounds and apparent per capita consumption in the United States was 87 pounds. The average annual rate of growth of apparent per capita consumption was 9.7 percent from 1950 to 1970; in the period 1960 to 1970, the rate of growth was 11.3 percent.

Further penetration of plastics into existing markets, and into new markets, is expected to continue. If the growth rates previously cited are extrapolated linearly, per capita consumption in the year 2000 could range from 1,400 pounds to 2,160 pounds. If, as seems more likely, per capita consumption of plastics levels off somewhere in the middle hundreds of pounds, say 500, and if the low census projection proves valid, minimum U.S. requirements for plastics in the year 2000 would be of the order of 135 billion pounds.

Plastics materials are obtained very largely by chemical processing of petroleum and natural gas raw materials. Imports are brought in on the basis of cost competition, not because of any domestic lack of raw materials or production capability. Process requirements for chemical elements or compounds not produced in this country, for catalytically promoted reactions, or for special metal alloys are lumped with other such requirements in the metals and minerals portions of this report. Even if per capita and total consumption in the year 2000 reach the maximum estimate, it does not appear that production of plastics materials would be constrained by lack of domestic raw materials. Cost and technological considerations may alter production and consumption patterns if North American oil shale and tar sands become the raw materials sources of the future, but overall requirements could be met.

Recycling and recovery.—At present there is little recovery and recycling of plastic materials, although developments are in progress. The common problem of sorting materials from waste processing operations is compounded in the case of plastics by the general requirement to separate one plastic material from another for almost all subsequent processing. Most new plastics materials sell in the range from 10 to 20 cents a pound at low profit margins, leaving little margin for expenditures on salvaging. Reclaimed material usually must be sold at 3 to 4 cents a pound less than new stock, and health regulations forbid the use of reclaimed material for food packaging.

Environment.—In the United States, plastics now constitute only about 2% of urban solid wastes. This portion is expected to rise slowly with time but is not expected to become a major component. Despite their small role in the solid waste problem, plastics materials' characteristic resistance to deterioration, and their visibility in litter, have contributed to the development of public opinion on their status as an environmental problem. Development of biodegradable plastics materials is under way, and by 1980 such materials are expected to be commercially available for most packaging applications.

RUBBER

Supply and demand.—Future new rubber consumption in the United States will be affected by the course of the general economy and more especially by developments in transportation. About three-quarters of total new rubber consumed in the United States goes into products used in some form of transportation. Therefore, rubber consumption in the future will be vitally affected by private and public decisions involving employment locations, housing, mass transportation, and so forth.

Many factors such as substitution of materials, the imponderables of social and transportation changes, and value judgments such as product quality, make it difficult to estimate future quantitative levels of total elastomer requirements. Based on the historic total rubber consumption growth rate of 4.2 percent annually and current consumption of 3 million tons annually, requirements in the year 2000 could exceed 10 million tons. Based on an assumption of continuing incremental growth in absolute terms, but at a decreasing percentage rate, total rubber consumption in the year 2000 would be about 6 million tons.

Natural rubber comes largely from southeast Asia. As an agricultural product, it is faced with many problems common to all such products. Natural rubber has one additional problem in that it takes 5–7 years for a tree to produce rubber after planting, and maximum yield does not occur for several more years. Therefore, changing natural rubber productive capacity takes a relatively long period of time. Although capacity will probably continue to increase, the increase will be much slower than the worldwide growth in demand for elastomers. The United States has no domestic production of natural rubber, and future domestic supply can only be viewed in terms of worldwide supply and demand with many political and economic imponderables.

The price of natural rubber fluctuates freely. With the development of improved and competitive synthetic rubbers, selling at relatively stable prices, the volatility of natural rubber price changes has tended to abate. The two major changes on the horizon for natural rubber are the use of stimulants to increase productivity (e.g. Ethrel) and the preparation of natural rubber to technical specifications.

Synthetic rubbers both compete with and supplement natural rubber. The total world demand for elastomers far exceeds the supply of natural rubber; hence, synthetic rubbers are needed to satisfy demand. In addition, the specialty synthetic rubbers are designed to be useful in areas where natural rubber would not be satisfactory. Because synthetic rubbers are organic polymers made from petroleum derivatives, their future availability and cost depend upon the availability of petroleum and the level of alternative uses of petroleum such as gasoline, fuel oil, and plastics materials. Hence, the future availability and price of synthetic rubber are tied closely to the many political, economic, and technical factors facing the worldwide petroleum industry.

Recycling and recovery.—Since the early development of the rubber industry during the mid-19th century, discarded rubber products (footwear, tires, etc.) have been converted into a useful material by partially reversing the curing process. This reclaimed rubber has some technical advantages and can be used as an extender to reduce product cost. During recent years, the price of natural and synthetic rubbers have dropped while the collection and processing of rubber scrap into reclaimed rubber has increased in cost. This has resulted in a decline of the reclaimed rubber industry. Because of the decline, the reclaiming of scrap tires has significantly decreased. Reclaimed rubber production could turn around and show some growth if the price of natural and synthetic rubbers rose significantly, if new uses are found for reclaimed rubber, and/or if an appropriate type of Government subsidy were instituted for the purpose of alleviating the scrap tire solid waste problem.

COAL

Supply and demand.—The demand for coal for direct use is primarily for the generation of electric power and secondarily for the production of coke for the steel industry. Coal use for general industrial purposes is declining gradually, and for household and commercial purposes is expected virtually to disappear by the year 2000.

Estimates of future coal demand fall within a wide range, the high and the low of the range being contingent principally on the extent to which nuclear power generation evolves, and on the extent to which new technology is developed for the production of steel with a minimal use of coke,

such as direct reduction. A relatively low nuclear posture in relation to total power requirements will mean high coal demand. Conversely, extensive and viable nuclear capabilities (which in turn will depend largely on uranium supplies, costs, and degree of success of breeder reactors) will mean substantially lessened requirements for coal. Notwithstanding other developments, if there is substantial need for synthetic gas or liquid fuel from coal, or if conversion processes become economically competitive with natural supplies, the demand for coal will be enormous. Taking best available projections domestic coal demand in 2000 will be at least double the consumption in 1970, but its percentage participation in the total energy demand picture will fall to 13.7 percent from 19.2 percent in 1970.

In the overall, present coal supply is more than adequate to meet current domestic requirements, with an excess available for export and generation of substantial credits to our international balance of payments. Supplies of low-sulfur coal are not adequate to meet needs, however. The United States is self-sufficient in coal to meet the high range of demand forecast for the balance of the century. It is completely independent of foreign sources of supply, although minor supplies from Western Canada are imported as a matter of convenience. Both average f.o.b. mine prices and railroad freight rates are trending upward. Adequate supplies of railroad cars are essential to coal availability since relatively little coal is stored at mines except for unit train shipments.

Reserves.—World reserves are of great magnitude, but for the most part are concentrated in a relatively few regions, i.e., the United States, Peoples Republic of China, and the U.S.S.R. with Europe as a whole in a "middle" category. U.S. coal reserves are considered to be more than adequate to meet all foreseeable demands. It is estimated that 390 billion tons are economically recoverable with current technology.

Costs of extraction have been held lower than they otherwise would have been by high productivity resulting from intensive underground mechanization and the use of advanced equipment in surface mining. Productivity at underground mines declined by 3 tons per man day in 1970, however, partially as a result of the transition to new operating procedures under the Coal Mine Health and Safety Act and of compliance with environmental requirements. Costs f.o.b. mines increased appreciably.

Environment.—Principal among the social and environmental problems facing coal are air pollution, health and safety in mining, the reclamation of mined land surfaces, water pollution from acid mine drainage, and the disposal of solid wastes. Unless and until economically viable solutions are developed through the desulfurization of coal, the elimination of pollutants from stack gas emissions, or the revision of sulfur standards, and satisfactory means are developed to assure the continued high level of surface mine production, vast reserves of coal will not be exploited, and remaining supplies will be at much higher cost

GAS

Supply and demand.—Projected gas demand to 1985 is at an average annual growth rate of about 4 percent, considerably less than the 6 percent rate recorded between 1950 and 1970. However, there is no certainty that gas reserves will be discovered and developed at a rate sufficient to meet such requirements. In 1968–70 the United States produced 62 trillion cubic feet of natural gas, but gross additions to proved reserves, excluding North Alaska, totaled only 34 trillion cubic feet. By the end of 1970, reserves were only 12 times the annual consumption rate, yet 10 years earlier, in 1960, the reserve-production ratio was 20 to 1.

Possible future sources of supply include additional Federal lands in the outer continental shelf areas; relatively undrilled areas onshore; imported pipeline gas from Canada as well as from Alaska's North Slope via Canada; liquefied natural gas from South America, Africa, and the U.S.S.R.; heavy explosive fracturing of reservior rocks which are of low permeability; and synthetic gas made from ample domestic reserves of coal, from petroleum, or from oil shale.

In 1970, demand for natural gas was 21,367 billion cubic feet (58.5 billion feet daily). This was about 33 percent of the Nation's total energy requirement. Average daily use of gas by 1975 is expected to be about 76.2 billion cubic feet; by 1985 it is forecast at 104.7 billion cubic feet daily. In the year 2000, the daily demand is forecast at 133.9 billion cubic feet, more than twice current demand. The projections are based on the same set of conditional assumptions used with petroleum.

Reserves.—To meet burgeoning demands for natural gas, and still maintain an adequate inventory of supply, it will be necessary to find and

develop gas reserves at annual rates nearly twice as great as the average of the past 5 years. There is Government and industry agreement that undiscovered domestic gas resources recoverable with current technology far exceed projected demands for natural gas through the year 2000. Estimates are that there are 2,100 trillion cubic feet to be found, about twice the volume needed by 2000. About 40 percent of these resources are in offshore areas under water depths to 200 meters.

Relatively small amounts of natural gas are imported via pipeline from Canada, and Mexico. There is little probability of such imports expanding substantially unless large new reserves are discovered. Therfore, significant increases in natural gas imports probably will be limited to liquid natural gas, which will come in via special tanker (LNG). Supplies of such gas are not, at this time, under long-term arrangements. Reliability and security of LNG supplies from foreign sources should be a major factor in development of any trade in this type of gas.

Environment.—Pollutants from natural gas when used as an energy source are either low, easily removed, or nonexistent. The major environmentally related problem concerns activities involved in finding and producing gas.

PETROLEUM

Supply and demand.—In 1970 the United States consumed petroleum products at an average daily rate of 14.7 million barrels. This furnished about 44 percent of the Nation's energy. Average daily use by 1975 is expected to be about 18 million barrels, representing an annual growth rate of about 4 percent.

Projections beyond 1975 become very difficult. Variables complicating near term projections include rates of economic growth, an apparent shift toward increased energy consumption relative to real gross national product, and potentials for sizable shifts to oil from other fuels as energy users seek to meet new environmental standards and as they encounter further limitations in natural gas supplies. In longer term forecasting, other unknowns must be considered. These include technological advances in nuclear energy and those aiming at clean use of coal in the production of synthetic oil and gas; Federal regulatory practices as they relate to natural gas; and changes in cost relationships and life styles.

A study by the Bureau of Mines considering such contingencies resulted in a wide range of demand possibilities. A best estimate indicates petroleum demand for the year 2000 at about 32.8 million barrels daily.

In 1970, the United States imported about 3.4 million barrels of oil daily. Given an average daily consumption of 14.7 million barrels, imports thus amounted to 23 percent of the Nation's requirements. If, domestic exploration and development continue their downward trend, large increases in imports are expected. By 1980 up to 8 million barrels daily of imported oil may be needed, a large part of which would come from Persian Gulf and North African countries. Most present U.S. imports come from Western Hemisphere countries, but they are not expected to to maintain their present role.

Reserves.—Proved reserves of crude oil and natural gas liquids, both onshore and in the U.S. offshore areas, amount to 39 billion barrels of crude oil and 7.7 billion barrels of natural gas liquids. Included are the 9.6 billion barrels in Alaska's North Slope, which will not be available until transportation has been developed.

The Department of the Interior has estimated that about 171 billion barrels of offshore crude and 246 billion barrels of onshore crude remain to be found, and are estimated recoverable under current technological and economic conditions, once they have been located. Proved reserves, however, in the lower 48 States continued declining in 1970 and were equivalent to only about 9 years of production at current rates.

Worldwide proved oil reserves continue to increase rapidly. At the end of 1970, foreign petroleum reserves totaled 570 billion barrels, of which an estimated 17 percent is under the control of Communist nations. Foreign Free World reserves are about 10 times those of the United States. The bulk of these are in the Persian Gulf countries, which account for 58 percent of the total. Together with Venezuela, Libya, Algeria, Nigeria, and Indonesia, they constitute the world's major petroleum exporters. Supplies of oil from each of these countries are subject to interdiction, embargo, enjoinment or other forms of restriction. Most of these nations are now members of the Organization of Petroleum Exporting Countries, under which its members seek the highest possible income from their oil production through increased ownership and control of oil producing holdings

and through higher oil prices and taxes. Payments for oil from OPEC countries by 1975 are expected to be at least 50 cents per barrel more than at present.

Recycling and recovery.—Except for re-refining and other uses of used lubricating oil, there is little recycling in the petroleum field which would add to supplies.

Environment.—The impact of current environmental considerations has mostly been felt in domestic exploration and development, notably in delaying Alaskan production, restricting Santa Barbara Channel development, postponing Federal offshore leasing, and rigid control of offshore production practices. Environmental concerns have also impacted on the siting of refineries and on deep water terminal facilities. Requirements for low sulphur fuel oils have increased imports of available supplies of such oils, and this demand has, and will, trigger higher prices in the countries of origin, in turn making costs to the U.S. consumer proportionately higher. Oil spills and disposal of oil field and refinery wastes pose special problems.

URANIUM

Supply and demand.—The Atomic Energy Commission estimate of fuel required for nuclear power plants through 1985 is shown below.

Uranium Requirements with Plutonium Recycle [1]

[Short tons uranium oxide]

Year	United States	
	Annual	Cumulative
1972	9,200	9,200
1973	10,600	19,800
1974	14,400	34,200
1975	18,200	52,400
1976	20,500	72,900
1977	23,800	96,700
1978	28,400	125,100
1979	32,600	157,700
1980	37,000	194,700
1981	42,100	236,800
1982	47,400	284,200
1983	53,200	337,400
1984	59,700	397,100
1985	66,600	463,700

[1] Assumes plutonium will be inserted in 1979 in 75% of the reactors.

The forecast considered projected growth in electricity demand, recent growth in nuclear power, fuel characteristics of current and planned plants, and utilization of plutonium generated in the reactors. Changing reactor technology will have little effect on the expected demand before 1985. However, in the 1986–2000 period, the introduction of breeder reactors could result in annual usage rates of uranium peaking early in the 1990's and then declining. On the other hand, if breeder reactors are not commercially used until the nineties, light-water reactors and high-temperature, gas-cooled reactors which require more uranium will continue to be the principal reactor types used. In this case, the annual demand for uranium will continue to increase at nearly the same rate shown until eight to ten years after successful commercial breeder introduction, after which requirements are likely to decline.

Domestic production of uranium was about 12,400 tons of uranium oxide in concentrate in 1971; foreign production was about 12,300 tons. Slippage of reactor construction has created a temporary oversupply of uranium expected to last at least two or three years. Capability to produce from conventional low cost deposits can be expected to increase as uranium demand rises. Production capability of current and planned plants could reach about 18,000 tons per year in 1973.

Introduction of breeder reactors, now expected by the late 1980's, would reduce uranium requirements and permit use of much higher cost uranium without significant effect on generating costs. In the interim, lower cost resources will be utilized. The U.S. resource base must be expanded to fill this demand. Prospects are good that with proper incentives and timely exploration adequate low cost resources can be developed.

The energy that can be derived from uranium is enormous compared to the volume of the fuel. Transportation of uranium, therefore, is not a significant portion of the cost of energy recovered, in marked contrast to coal, oil, and gas.

Most non-Communist world uranium supply is controlled by the United States, Canada, South Africa, and France. These countries should be reliable suppliers for the next decade or two, until demands exceed their capabilities. Foreign resources are expected to be a primary source of uranium for Western Europe and Japan. Production of 22,000 tons of U_3O_8 may be attainable from current and planned foreign operations by 1975. Continued expansion of foreign and U.S. resources and production capability will be needed to meet projected demands.

Reserves.—Domestic reserves on January 1, 1972 were estimated by the AEC to be 275,000 tons U_3O_8 at $8 per pound and 430,000 tons U_3O_8 at

$10 per pound. Foreign (non-Communist) countries have an estimated reserve of 720,000 tons at $10 per pound. The United States, Canada, South West Africa, and France account for 87 percent of the total of 1,150,000 tons U_3O_8.

United States exploration drilling activity has been at record levels in recent years but has decreased from 30 million feet per year in 1969 to 15.5 million in 1971. Such low rates may be insufficient to maintain an adequate U.S. reserve base.

Environment.—Uranium will be used primarily for generation of electricity. The fissioning of the uranium will generate relatively small volumes of highly radioactive materials. Only a minute portion of this radioactivity will reach the environment. The bulk of the radioactive wastes will be separated during recovery of the nuclear fuel for eventual storage in solid form in a Federal repository that will effectively isolate it from man's environment.

Waste heat from nuclear plants is higher than from some modern fossil plants because of lower thermal efficiency. Careful plantsiting and use of cooling devices can minimize the environmental effects of the waste heat. In addition, advanced reactor designs will be of higher thermal efficiency, reducing the heat to be dissipated.

Recycling.—Since only a small portion of the uranium in a reactor core is consumed during a reactor cycle, reprocessing of wastes and irradiated cores is planned as a normal operational procedure. In addition, plutonium, generated in the reactor will be recovered at the same time. While special techniques are required, the technology is well developed.

APPENDIX B

Statistical Tables

Iron Consumption for Production of Iron and Steel Products

[Million short tons contained iron]

	Primary			Secondary			Industrial demand	Net steel imports
	U.S. Mine production	Net imports	Apparent demand [1]	U.S. Supply	Net exports	Apparent demand [1]		
1950	54.7	5.0	62.3	32.6	−0.6	33.4	95.7	−1.6
1951	66.7	5.4	66.8	36.6	−.2	37.8	104.6	−.9
1952	55.5	4.2	58.8	36.9	+.2	34.2	93.0	−2.8
1953	67.1	5.7	69.7	38.3	.1	38.0	107.7	−1.3
1954	44.7	9.2	54.9	29.9	1.5	28.2	83.1	−2.0
1955	59.4	13.3	74.6	40.7	5.0	35.8	110.4	−3.1
1956	56.6	16.5	70.7	43.0	6.1	36.7	107.4	−3.0
1957	61.4	18.2	73.7	37.6	6.6	29.5	103.2	−4.1
1958	40.5	16.1	54.5	25.9	2.6	22.6	77.1	−1.1
1959	36.2	22.5	58.5	33.7	4.6	28.7	87.2	2.7
1960	53.6	19.9	64.8	34.0	7.8	26.9	91.7	.4
1961	43.5	13.9	60.6	34.8	9.4	25.8	86.4	1.2
1962	44.2	18.8	61.3	30.2	4.9	25.7	87.0	2.1
1963	46.4	18.2	67.6	35.6	6.2	30.0	97.6	3.2
1964	54.2	25.1	81.0	39.4	7.6	32.4	113.4	3.0
1965	56.1	27.4	83.3	41.8	6.0	35.5	118.8	7.9
1966	57.6	28.0	84.5	42.1	5.5	36.0	120.5	9.1
1967	54.8	27.4	80.5	40.1	7.5	33.2	113.7	9.8
1968	56.3	28.2	83.3	40.0	6.4	33.7	117.0	15.8
1969	59.0	25.7	88.3	45.9	9.0	38.2	126.5	8.8
1970	59.4	27.6	83.9	44.7	10.6	33.0	116.9	6.3
2000	50.0	103.0	153.0	[2] 89.8	[2] 22.8	67.0	220.0	[3] 28.0

[1] Adj for inventory changes.
[2] Extrapolated to 2000 at same ratio to total in 1970.
[3] Extrapolated to 2000 at same ratio to total for last 5 years.

Chromium

[Thousands short tons contained chromium]

	U.S. mine production	Imports		Apparent primary demand [1]	Secondary recovery	Industrial demand
		Ore	Alloys and Chemicals			
1951	2	418	16	285	25	310
1952	7	490	12	356	25	381
1953	17	645	21	390	38	428
1954	43	416	10	265	22	287
1955	42	524	20	466	33	499
1956	56	629	27	549	34	583
1957	46	673	33	529	28	557
1958	40	373	19	366	24	390
1959	28	455	68	395	27	422
1960	28	391	36	353	28	381
1961	21	387	20	319	29	348
1962	0	420	35	283	32	315
1963	0	414	24	425	36	461
1964	0	442	20	547	44	591
1965	0	469	43	515	50	565
1966	0	575	77	546	57	603
1967	0	380	42	421	51	472
1968	0	342	47	451	51	502
1969	0	346	46	475	82	557
1970	0	443	50	462	67	529
2000	0	[2] 1,047	[2] 73	1,120	140	1,260

[1] Apparent primary demand adjusted for Government purchase and sale and industry inventory changes.
[2] Projections to 2000 on 1970 ratio to total demand.

Cobalt

[Thousand pounds contained cobalt]

	U.S. mine production	Net imports [1]	Apparent primary demand	Secondary recovery	Industrial demand
1951	903	9,030	9,933	894	10,827
1952	1,363	9,883	11,246	1,368	12,614
1953	1,259	9,489	10,748	1,541	12,289
1954	1,996	5,354	7,350	789	8,139
1955	2,609	7,764	10,373	514	10,887
1956	3,595	6,985	10,580	395	10,975
1957	4,144	7,770	11,914	363	12,277
1958	4,844	2,698	7,542	355	7,897
1959	2,994	12,601	15,595	261	15,856
1960	2,247	6,683	8,930	240	9,170
1961	1,045	10,518	11,563	178	11,741
1962	721	12,901	13,622	207	13,829
1963	948	11,054	12,002	246	12,248
1964	1,084	12,747	13,831	148	13,979
1965	1,186	13,111	14,297	87	14,384
1966	1,215	16,685	17,900	48	17,948
1967	1,168	14,052	15,220	120	15,340
1968	1,176	13,265	14,441	143	14,584
1969	1,003	16,745	17,748	328	18,076
1970	697	15,493	16,190	69	16,259
2000	0	24,700	24,700	500	25,200

[1] Net imports adjusted for Government purchase and sale, industry stocks and exports.

Columbium

[Thousands pounds contained columbium]

	U.S. mine production	Net imports [1]	Industrial demand
1951	1	199	200
1952	1	399	400
1953	3	497	[illegible]
1954	6	194	200
1955	2	458	460
1956	41	779	820
1957	0	1,224	1,224
1958	81	705	786
1959	36	1,154	1,190
1960	0	2,458	2,458
1961	0	1,510	1,510
1962	0	2,522	2,522
1963	0	2,376	2,376
1964	0	3,638	3,638
1965	0	4,544	4,544
1966	0	4,672	4,672
1967	0	6,633	6,633
1968	0	4,307	4,307
1969	0	4,660	4,660
1970	0	5,056	5,056
2000	0	19,200	19,200

[1] Net imports adjusted for Government purchases and sales, exports and changes in inventory.

Vanadium

[Short tons contained vanadium]

	U.S. mine production	Imports	Exports	Industrial demand [1]
1951	2,228	521	31	2,069
1952	2,164	527	134	1,906
1953	2,506	[illegible]	45	2,018
1954	3,151	198	56	1,064
1955	3,669	93	975	1,890
1956	3,937	----------	998	2,210
1957	3,612	----------	567	1,990
1958	2,791	----------	669	1,400
1959	4,092	11	1,316	2,067
1960	5,495	10	3,771	2,223
1961	5,817	----------	2,141	2,552
1962	4,750	----------	1,122	3,684
1963	3,897	241	628	3,334
1964	5,049	245	1,282	4,718
1965	6,160	26	1,038	7,208
1966	6,496	76	1,127	6,516
1967	5,921	49	964	6,088
1968	6,149	610	602	5,776
1969	5,906	2,491	[illegible]	7,975
1970	5,594	2,024	2,051	7,066
2000	13,000	18,000	0	31,000

[1] Adjusted for Government purchases and sales and industry inventory changes.

Manganese

[Thousand short tons contained manganese]

	U.S. Mine production	Imports		Industrial demand [1]
		Ore	Alloys	
1950	239	717	88	1,034
1951	247	862	95	1,215
1952	209	1,249	51	1,070
1953	269	1,613	[illegible]	1,222
1954	177	1,021	45	794
1955	263	998	52	1,237
1956	247	1,051	130	889
1957	257	1,434	263	1,267
1958	196	1,152	58	953
1959	153	1,145	83	1,061
1960	117	1,215	103	1,077
1961	78	988	184	842
1962	73	933	145	978
1963	94	993	132	1,096
1964	79	984	170	1,216
1965	83	1,221	211	1,373
1966	88	1,223	221	1,353
1967	73	978	193	1,207
1968	48	870	183	1,150
1969	93	992	257	1,317
1970	66	847	238	1,327
2000	0	[2] 1,840	[2] 520	2,360

[1] Industrial demand adjusted for Government stocks and purchases and industry stocks.
[2] Projection to 2000 at same ratio as in 1970.

Nickel

[Thousand short tons contained nickel]

	U.S. mine production	Net imports [1]	Apparent primary demand [2]	Secondary demand	Industrial demand [3]
1951	0.8	89.0	86.7	23.6	104.6
1952	.7	103.0	101.4	22.5	118.3
1953	.6	105.0	105.7	23.4	111.1
1954	.9	119.2	94.7	24.1	108.4
1955	3.8	122.7	109.3	32.5	119.6
1956	6.7	127.9	127.6	38.7	158.0
1957	10.1	128.0	122.5	32.9	143.9
1958	11.8	78.0	79.0	23.6	83.5
1959	11.6	106.3	112.7	27.4	119.7
1960	12.6	93.1	108.2	24.3	145.9
1961	11.2	119.8	134.2	29.2	163.4
1962	11.2	115.0	127.9	31.3	159.2
1963	11.5	109.0	120.0	41.7	161.7
1964	12.2	117.0	132.1	50.9	183.0
1965	13.5	157.4	190.4	51.4	241.8
1966	13.3	129.2	228.8	63.1	291.9
1967	14.6	134.6	182.5	52.3	234.8
1968	15.2	137.2	157.9	36.6	194.5
1969	15.6	124.4	149.6	71.0	220.6
1970	15.3	146.3	155.7	64.7	204.4
2000	42.5	342.5	385.0	165.0	550.0

[1] Imports and exports of virgin nickel exclude nickel shapes and forms.
[2] Adjusted for inventory changes and Government purchase and sale.
[3] Adjusted for inventory changes.

Tungsten

[Thousands pounds contained tungsten]

	U.S. mine production	Imports	Exports	Apparent primary demand [1]	Secondary demand	Industrial demand
1951	5,973	6,377		11,410		11,410
1952	7,244	17,416	11	8,634		8,634
1953	9,128	28,060	13	7,734		7,734
1954	13,030	24,188	40	4,037		4,037
1955	15,619	20,700	35	8,967		8,967
1956	14,027	20,860	121	9,061		9,061
1957	5,254	14,018	168	8,544		8,544
1958	3,605	6,542	23	5,320		5,320
1959	3,473	5,435	1	9,835		9,835
1960	6,669	5,178	653	11,405	200	11,605
1961	8,188	2,744	214	10,829	300	11,129
1962	8,280	3,709	41	13,441	250	13,691
1963	5,384	3,882	51	10,688	375	11,061
1964	8,798	2,737	79	11,911	400	12,311
1965	7,566	3,495	11	13,488	380	13,868
1966	7,166	4,203	101	17,633	425	18,058
1967	7,170	2,004	974	13,410	450	13,860
1968	7,496	1,824	623	12,608	500	13,108
1969	6,904	1,534	7,152	15,556	500	16,056
1970	8,105	1,284	19,470	16,200	500	16,700
2000	2,260	71,740		74,000	2,400	76,400

[1] Adjusted for Government purchase and sale, and industry inventory changes.

Aluminum

[Thousand short tons aluminum content]

Year	U.S. industrial demand [1]	Old scrap	U.S. primary demand [1]	Total net imports [1]	Industrial and Government stockpile changes (+ or −)	U.S. mine production	Rest of world mine production
1951	999	77	922	748	−344	518	1,834
1952	1,132	71	1,061	883	−289	467	2,297
1953	1,449	79	1,370	1,256	−328	442	2,545
1954	1,050	66	984	1,283	−858	559	2,949
1955	1,640	100	1,540	1,272	−233	501	3,354
1956	1,617	97	1,520	1,437	−405	458	3,590
1957	1,460	98	1,362	1,728	−762	396	4,036
1958	1,447	80	1,367	1,971	−971	367	4,269
1959	2,205	104	2,101	1,990	−365	476	4,515
1960	1,680	95	1,585	1,912	−886	559	5,513
1961	2,237	156	2,081	2,140	−403	344	6,049
1962	2,376	167	2,209	2,491	−665	383	6,442
1963	2,648	159	2,489	2,228	−166	427	6,250
1964	2,954	162	2,792	2,339	5	448	6,820
1965	3,398	205	3,193	2,821	−91	463	7,684
1966	3,780	187	3,593	3,082	8	503	8,399
1967	3,702	175	3,527	3,106	−42	463	9,165
1968	3,928	181	3,747	3,251	30	466	9,537
1969	4,269	181	4,088	3,339	233	516	10,756
1970	4,128	177	3,951	3,720	−352	583	11,957
2000	28,400	2,000	26,400			503	

[1] Includes bauxite and alumina.

Beryllium

[Short tons beryllium content]

Year	U.S. industrial demand	Old scrap	U.S. primary demand	Total net imports [1]	Industrial and government stockpile changes (+ or −)	U.S. mine production	Rest of world mine production
1951	125	0	125	169	−63	19	244
1952	149	0	149	222	−94	21	307
1953	107	0	107	310	−233	30	295
1954	79	0	79	229	−177	27	276
1955	160	5	155	241	−106	20	329
1956	177	2	175	450	−293	18	498
1957	174	0	174	188	−35	21	429
1958	242	0	242	155	69	18	289
1959	330	0	330	243	74	13	432
1960	388	0	388	358	16	14	471
1961	414	8	406	279	w.	w.	471
1962	369	15	354	237	w.	w.	401
1963	384	24	360	201	w.	w.	262
1964	251	4	247	137	w.	w.	197
1965	311	13	298	257	w.	w.	245
1966	350	15	335	60	w.	w.	182
1967	360	17	343	342	w.	w.	218
1968	353	29	324	113	w.	w.	282
1969	469	6	463	144	w.	w.	353
1970	380	2	378	181	w.	w.	334
2000	1,790	20	1,770	...	.	82	...

[1] Mostly beryl.
w. Data withheld by the Bureau of Mines to avoid disclosing of company confidential information.

Copper

[Thousand short tons of copper]

Year	U.S. total demand	Secondary		U.S. primary demand	Total net imports	Industrial and Government stockpile changes (+ or −)	Refined production from U.S. mines	U.S. mine production	Rest of world mine production
		New	Old						
1951	2,183	478	458	1,247	361	−66	952	928	1,972
1952	2,203	503	415	1,285	482	−66	923	925	2,095
1953	2,254	550	429	1,275	525	−182	932	926	2,364
1954	2,011	549	407	1,055	369	−156	842	835	2,275
1955	2,283	486	515	1,282	347	−62	997	999	2,421
1956	2,319	578	468	1,273	332	−139	1,080	1,104	2,686
1957	2,134	523	444	1,167	220	−103	1,050	1,087	2,803
1958	1,813	386	411	1,016	94	−80	1,002	979	2,801
1959	2,145	460	471	1,214	357	61	796	825	3,215
1960	1,977	441	429	1,107	107	−121	1,121	1,080	3,570
1961	2,086	438	411	1,237	7	49	1,181	1,165	3,575
1962	2,277	506	416	1,355	160	−19	1,214	1,228	3,647
1963	2,399	552	422	1,425	185	21	1,219	1,213	3,736
1964	2,659	619	474	1,566	220	87	1,259	1,247	3,865
1965	2,866	740	513	1,613	188	89	1,336	1,352	3,967
1966	3,275	842	535	1,898	249	296	1,353	1,429	4,056
1967	2,792	760	483	1,549	458	244	847	954	4,270
1968	2,811	750	521	1,540	435	−56	1,161	1,205	4,436
1969	3,097	826	575	1,696	205	22	1,469	1,545	4,668
1970	2,820	744	504	1,572	155	−104	1,521	1,720	4,847
2000	9,700	2,600	1,700	5,400	...	...	...	2,380	...

Lead

[Thousand short tons—lead content]

Year	U.S. industrial demand	Old scrap	U.S. primary demand	Total net imports	Industrial and Government stockpile changes (+ or −)	U.S. smelters domestic ore	U.S. mine production	Rest of world mine production
1951	1,078	442	636	262	14	360	388	1,502
1952	1,164	412	752	604	−248	396	390	1,640
1953	1,191	429	762	535	−111	338	343	1,757
1954	1,104	425	679	447	−95	327	325	1,945
1955	1,160	449	711	431	−46	326	338	2,092
1956	1,166	446	720	458	−94	356	353	2,137
1957	1,219	432	787	515	−86	358	338	2,302
1958	891	343	548	576	−305	277	267	2,323
1959	1,010	393	617	382	3	232	256	2,314
1960	948	408	540	359	−49	230	247	2,373
1961	1,085	391	694	429	−36	301	262	2,368
1962	1,048	393	655	398	−3	[illegible]	237	2,528
1963	1,102	427	675	386	[illegible]	244	253	2,552
1964	1,121	470	651	357	85	209	[illegible]	2,449
1965	1,194	496	698	332	[illegible]	308	301	2,666
1966	1,268	485	783	407	51	325	327	2,812
1967	1,226	477	749	482	3	264	317	2,842
1968	1,379	471	908	452	91	365	359	2,940
1969	1,408	516	892	404	−37	525	509	3,014
1970	1,335	506	829	378	−86	537	572	3,168
2000	2,730	1,300	1,430				470	

Magnesium

[Thousand short tons—magnesium content]

Year	U.S. industrial demand [1]	Old scrap	U.S. primary demand [1]	Total net imports [1]	Industrial and Government stockpile changes (+or−)	U.S. primary production [1]	Rest of world primary production [1]
1951	952	6	946	29	−2	919	1,879
1952	910	7	903	−23	−9	935	1,959
1953	1,094	6	1,088	[illegible]	−1	1,060	2,055
1954	719	3	716	24	−6	698	2,131
1955	1,002	5	997	38	−7	966	2,242
1956	1,145	5	1,140	53	−3	1,090	2,326
1957	1,135	5	1,130	54	−37	1,113	2,447
1958	877	5	872	28	12	832	2,578
1959	1,073	5	1,068	36	17	1,015	2,721
1960	1,032	[illegible]	1,028	12	14	1,002	2,882
1961	1,074	[illegible]	1,069	−45	18	1,096	3,056
1962	1,081	4	1,077	15	−1	1,063	3,221
1963	1,180	2	1,178	−2	−1	1,181	3,574
1964	1,244	4	1,240	−21	2	1,259	3,775
1965	1,299	[illegible]	1,295	−10	3	1,302	3,976
1966	1,398	[illegible]	1,394	54	22	1,318	4,029
1967	1,192	4	1,188	33	5	1,150	4,118
1968	1,175	4	1,171	29	4	1,138	4,261
1969	1,246	3	1,243	[illegible]	23	1,212	4,365
1970	1,156	3	1,153	−3	15	1,141	5,117
2000	2,770	30	2,740			1,812	

[1] Sum of total nonmetal and metal.

Mercury

[76-pound flasks]

Year	U.S. industrial demand	Old scrap	U.S. primary demand	Total net imports	Industrial and Government stock pile changes	U.S. mine production	Rest of world mine production
1951	56, 848	2, 000	54, 848	44, 011	3, 544	7, 293	139, 707
1952	42, 556	2, 500	40, 056	68, 027	−40, 518	12, 547	138, 453
1953	52, 259	2, 800	49, 459	84, 322	−49, 200	14, 337	145, 663
1954	42, 796	6, 100	36, 696	62, 991	−44, 838	18, 543	161, 457
1955	57, 185	10, 030	47, 155	20, 230	7, 970	18, 955	166, 045
1956	54, 143	5, 850	48, 293	48, 904	−24, 788	24, 177	196, 823
1957	52, 889	5, 800	47, 089	40, 255	−27, 791	34, 625	205, 375
1958	52, 617	5, 400	47, 217	29, 719	−20, 560	38, 067	207, 933
1959	54, 895	4, 950	49, 945	29, 067	−10, 378	31, 256	191, 744
1960	51, 167	5, 350	45, 817	18, 841	−6, 247	33, 223	208, 777
1961	55, 763	8, 360	47, 403	12, 062	3, 679	31, 662	208, 338
1962	65, 301	5, 800	59, 501	31, 035	2, 189	26, 277	218, 723
1963	77, 963	6, 520	71, 443	42, 899	9, 427	19, 117	220, 535
1964	81, 354	7, 519	73, 835	40, 723	18, 970	14, 142	240, 991
1965	73, 560	14, 906	58, 654	9, 801	29, 271	19, 582	248, 291
1966	71, 509	8, 535	62, 974	33, 924	7, 042	22, 008	242, 986
1967	69, 517	10, 696	58, 821	20, 797	14, 240	23, 784	208, 289
1968	75, 422	10, 570	64, 852	16, 357	19, 621	28, 874	230, 820
1969	77, 372	10, 573	66, 799	30, 233	6, 926	29, 640	260, 403
1970	61, 503	7, 348	54, 155	16, 969	9, 883	27, 303	256, 625
2000	102, 000	22, 000	80, 000			44, 000	

Platinum

[Thousand troy ounces]

Year	U.S. industrial demand	Old scrap	U.S. primary demand	Total net imports	Industrial and Government stockpile changes (+ or −)	U.S. refinery production	U.S. mine production	Rest of world mine production
1951	210	22	188	320	−154	22	27	336
1952	229	28	201	229	−49	21	25	350
1953	277	29	248	334	−149	13	16	405
1954	320	30	290	378	−106	18	18	479
1955	467	31	436	483	−62	15	15	554
1956	431	58	373	453	−95	15	15	590
1957	348	47	301	315	−26	12	12	713
1958	264	35	229	248	−28	9	8	289
1959	363	56	307	325	−28	10	10	530
1960	325	37	288	223	55	10	12	625
1961	283	49	234	238	−21	17	17	614
1962	304	68	236	190	32	14	14	683
1963	424	51	373	391	−39	21	20	789
1964	451	63	388	198	174	16	14	1, 062
1965	411	51	360	302	47	11	10	1, 257
1966	691	47	644	258	368	18	18	1, 285
1967	634	121	513	304	202	7	7	1, 346
1968	580	111	469	269	195	5	7	1, 442
1969	516	122	394	302	83	9	11	1, 472
1970	516	109	407	293	106	8	7	1, 956
2000	1, 295	295	1, 000				0	

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Tin

[Long tons—tin content]

Year	U.S. industrial demand	Old scrap	U.S. primary demand	Total net imports [1]	Industrial and Government stockpile changes (+ or −)	U.S. mine production	Rest of world mine production
1951	88,169	30,745	57,424	58,506	−1,170	88	169,312
1952	78,418	28,800	49,618	102,869	−53,350	99	174,001
1953	85,640	27,600	58,040	111,873	−53,889	56	189,644
1954	82,891	26,190	56,701	91,979	−35,483	205	188,595
1955	90,483	28,340	62,143	85,938	−23,894	99	197,101
1956	90,324	29,440	60,884	79,331	−18,447	0	199,500
1957	82,507	24,260	58,247	56,191	2,056	0	200,400
1958	72,585	22,810	49,775	.W.	W.	0	153,500
1959	77,373	23,700	53,673	.W.	W.	50	161,450
1960	80,560	22,050	58,510	.W.	W.	10	180,390
1961	78,250	21,690	56,560	[2]48,535	8,025	W.	184,100
1962	79,085	21,040	58,045	[2]47,684	10,361	W.	186,900
1963	78,303	22,332	55,971	[2]43,278	12,696	W.	191,100
1964	82,780	23,508	59,272	31,879	27,328	55	193,400
1965	83,966	25,076	58,820	41,038	17,805	47	201,400
1966	85,462	25,349	60,113	42,580	17,436	97	208,000
1967	80,638	22,667	57,971	[2]50,794	7,177	W.	214,200
1968	81,961	22,495	59,466	[2]56,316	3,150	W.	[2]228,332
1969	80,505	22,775	57,730	[2]52,392	5,338	W.	[2]224,078
1970	73,028	20,001	53,027	[2]50,769	2,258	W.	[2]226,569
2000	130,000	40,000	90,000			0	

[1] Ore and metal.
[2] Computed neglecting U.S. mine production.
W.—Data withheld by Bureau of Mines to avoid disclosing of company confidential information.

Titanium

[Thousand short tons—titanium content]

Year	U.S. industrial demand	U.S. primary demand	U.S. demand for primary metal	Total net imports	Industrial and Government stockpile changes (+ or −)	U.S. mine production	Rest of world mine production
1951	233	233	—	45	17	171	.77
1952	221	221	1	54	−2	169	186
1953	256	256	1	57	5	164	237
1954	266	266	3	91	1	174	272
1955	315	315	5	110	18	187	326
1956	376	376	13	147	9	220	450
1957	342	342	10	191	−91	242	510
1958	291	291	5	126	−14	179	448
1959	362	362	6	128	31	203	509
1960	338	338	8	107	−24	255	556
1961	353	353	9	87	15	251	728
1962	351	351	10	82	11	258	680
1963	386	386	11	119	−23	290	720
1964	442	442	14	142	−17	317	832
1965	444	444	15	108	−28	304	895
1966	463	463	22	174	−13	302	975
1967	452	452	25	180	−23	295	1,050
1968	486	486	18	185	−4	305	1,124
1969	535	535	27	183	50	302	1,281
1970	490	490	24	247	−33	276	1,498
2000	2,090	1,978				576	

Zinc

[Thousand short tons—zinc content]

Year	U.S. Industrial demand	Old scrap	U.S. primary demand	Total net imports [1]	Industrial and Government stockpile changes (+ or −)	U.S. mine production	Rest of world mine production
1951	1,068	49	1,019	349	−11	681	1,978
1952	962	55	907	503	−262	666	2,274
1953	1,104	53	1,051	726	−222	547	2,446
1954	983	68	915	586	−144	473	2,457
1955	1,238	66	1,172	657	0	515	2,685
1956	1,126	74	1,052	763	−253	542	2,888
1957	1,051	77	974	786	−344	532	2,938
1958	1,018	70	948	663	−127	412	2,958
1959	1,127	74	1,053	657	−29	425	3,016
1960	1,024	68	956	513	8	435	3,245
1961	1,036	59	977	501	12	464	3,381
1962	1,169	62	1,107	583	19	505	3,425
1963	1,166	63	1,103	494	80	529	3,507
1964	1,178	68	1,110	454	81	575	3,865
1965	1,430	82	1,348	584	153	611	4,130
1966	1,553	[illegible]	1,467	808	86	573	4,388
1967	1,402	80	1,322	749	24	549	4,769
1968	1,491	80	1,411	827	55	529	4,970
1969	1,582	82	1,500	930	17	553	5,274
1970	1,374	72	1,302	801	−36	534	5,527
2000	3,200	200	3,000			486	

[1] Includes metal, ore, and compounds.

Bituminous coal and lignite

[Thousand short tons]

Year	Production	Imports	Exports	Consumption
1951	533,665	292	56,722	468,904
1952	466,841	262	47,643	418,757
1953	457,290	227	33,760	426,798
1954	391,706	199	31,041	363,060
1955	464,633	337	51,277	423,412
1956	500,874	356	68,553	432,858
1957	492,704	367	76,342	413,668
1958	410,446	307	50,293	336,703
1959	412,028	375	37,227	366,703
1960	415,512	260	36,491	380,429
1961	402,977	164	34,970	374,405
1962	422,149	232	38,413	387,774
1963	458,928	267	47,078	409,225
1964	486,998	293	47,969	431,116
1965	512,088	184	50,181	459,164
1966	533,881	178	49,302	486,266
1967	552,626	227	49,528	480,416
1968	545,245	224	50,637	498,830
1969	560,505	109	56,234	507,275
1970	602,932	36	70,908	517,018

Petroleum[1]*—U.S. production, imports, exports, and consumption*

[Million 42-gallon barrels]

Year	Production		Imports	Exports	Consumption
	Crude oil	Natural gas liquids			
1951	2,247.7	204.8	309.3	142.3	2,573.8
1952	2,298.8	223.4	350.0	145.3	2,675.0
1953	2,357.1	238.6	378.3	133.0	2,788.4
1954	2,315.0	252.1	385.2	116.9	2,845.0
1955	2,484.4	281.4	456.2	120.5	3,100.5
1956	2,617.3	292.7	527.5	143.3	3,227.8
1957	2,616.9	295.0	576.8	191.6	3,234.5
1958	2,449.0	294.8	623.2	86.4	3,343.2
1959	2,574.6	320.8	649.6	77.1	3,477.2
1960	2,574.9	340.1	664.1	73.9	3,585.8
1961	2,621.8	361.7	699.7	63.6	3,641.3
1962	2,676.2	372.2	759.8	61.4	3,796.0
1963	2,752.7	400.9	774.7	76.0	3,921.4
1964	2,786.8	422.5	826.7	73.9	4,034.2
1965	2,848.5	441.6	900.8	68.3	4,202.0
1966	3,027.8	486.6	939.2	72.4	4,410.8
1967	3,215.7	514.5	926.0	112.1	5,584.5
1968	3,329.0	550.3	1,039.4	84.5	4,901.8
1969	3,371.8	580.2	1,155.6	84.9	5,159.9
1970	3,517.5	605.9	1,248.1	94.4	5,364.0

[1] Includes natural gas liquids.

Natural gas—U.S. production, imports, exports, and consumption

[Billion cubic feet]

Year	Production[1]	Imports	Exports	Consumption
1951	7,457		24	7,003
1952	8,013	8	27	7,498
1953	8,397		28	7,870
1954	8,743	7	29	8,259
1955	9,405	11	31	8,920
1956	10,082	10	36	9,502
1957	10,680	38	42	10,064
1958	11,030	136	39	10,626
1959	12,046	134	18	11,585
1960	12,771	156	11	12,269
1961	13,254	219	11	12,750
1962	13,877	402	16	13,612
1963	14,747	406	17	14,341
1964	15,547	441	17	15,118
1965	16,040	456	26	15,599
1966	17,207	480	25	16,759
1967	18,171	565	82	17,685
1968	19,322	653	94	18,957
1969	20,698	727	51	20,388
1970	21,921	821	70	21,367

[1] Marketed.

Uranium

[Short tons uranium oxide]

Year	Production		U.S. AEC purchases		U.S. commercial purchases domestic sources only[3]
	United States[1]	Foreign[2]	Domestic	Foreign sources	
Pre-1957	14,000	18,900	14,200	33,000	
1957	8,500	13,200	8,600	11,800	
1958	12,400	23,700	12,600	18,800	
1959	16,200	27,000	16,400	18,600	
1960	17,600	22,900	17,800	15,800	
1961	17,300	18,700	17,400	12,900	
1962	17,000	16,800	17,000	11,700	
1963	14,200	16,200	14,200	8,800	
1964	11,800	14,200	11,800	5,300	
1965	10,400	9,400	10,400	2,700	
1966	10,600	9,300	9,500	2,000	100
1967	11,200	9,100	8,400		400
1968	12,300	10,000	7,300		5,200
1969	11,600	11,300	6,200		4,300
1970	12,900	11,400	2,510		9,200
1971	12,400	12,300			13,000

[1] Domestic producers delivered 4800 tons U_3O_8 of this production to foreign buyers in the 1966–71 period.
[2] European nuclear energy agency reports uranium production and short-term demand, 1969 and 1970. (Does not include Congo.)
[3] AEC regulations prohibit use of foreign uranium in domestic reactors.

Measures of economic growth, population, and prices, 1950–71

Year	Gross national product		Disposable personal income		Expenditures for new construction		Business expenditures for new plant and equipment	Number of housing starts	Mobile homes [2]	Population [3]	Index of industrial production			Wholesale price index—all commodities	Consumer price index [4]—all items
	1967 [1] dollars	Current dollars	1967 [1] dollars	Current dollars	1967 [1] dollars	Current dollars					Total	Furniture and fixtures	Containers		
	Billions	*Billions*	*Billions*	*Billions*	*Billions*	*Billions*	*Billion dollars*	*Thousand units*	*Thousand units*	*Millions*	*1967=100*	*1967=100*	*1967=100*	*1967=100*	*1967=100*
1950	417.8	284.8	285.6	206.9			20.2			152.3				81.8	72.1
1951	450.8	328.4	292.5	226.6			25.5			154.9				91.1	77.8
1952	464.6	345.5	301.2	238.3			26.4			157.6				88.6	79.5
1953	485.4	364.6	315.1	252.6			28.2			160.2				87.4	80.1
1954	478.6	364.8	318.4	257.4			27.2			163.0	51.9	57.0	55.7	87.6	80.5
1955	515.0	398.0	339.4	275.3			29.5			165.9	58.5	66.2	61.1	87.8	80.2
1956	524.5	419.2	353.9	293.2			35.7			168.9	61.1	68.8	62.1	90.7	81.4
1957	532.0	441.1	361.3	308.5			37.9			172.0	61.9	68.8	61.6	93.3	84.3
1958	525.9	447.3	364.7	318.8	61.9	50.2	31.9			174.9	57.9	65.0	62.2	94.6	86.6
1959	559.6	483.7	381.0	337.3	67.4	55.3	33.6	1,554	121	177.8	64.8	72.6	67.9	94.8	87.3
1960	573.4	503.7	389.2	350.0	65.8	54.6	36.8	1,296	104	180.7	66.2	71.8	68.2	94.9	88.7
1961	584.6	520.1	401.2	364.4	67.0	56.3	35.9	1,365	90	183.7	66.7	70.6	72.0	94.5	89.6
1962	622.9	560.3	420.2	385.3	69.7	60.0	38.4	1,492	118	186.5	72.2	77.6	75.0	94.8	90.6
1963	647.9	590.5	436.2	404.6	73.4	64.6	40.8	1,642	151	189.2	76.5	80.6	77.4	94.5	91.7
1964	683.1	632.4	466.7	438.1	74.9	67.4	47.0	1,561	191	191.8	81.7	85.9	82.0	94.7	92.9
1965	726.4	684.9	497.7	473.2	78.9	73.4	54.4	1,510	216	194.2	89.2	93.1	88.8	96.6	94.5
1966	773.8	749.9	525.1	511.9	79.2	76.0	63.5	1,196	217	196.5	97.9	101.0	96.5	99.8	97.2
1967	793.9	793.9	546.3	546.3	77.5	77.5	65.5	1,322	240	198.6	100.0	100.0	100.0	100.0	100.0
1968	830.8	864.2	570.8	591.0	81.7	86.6	67.8	1,546	318	200.6	105.7	105.4	105.5	102.5	104.2
1969	852.1	929.1	587.6	634.2	81.6	93.3	75.6	1,500	413	202.6	110.7	107.4	117.4	106.5	109.8
1970 [5]	846.6	974.1	608.1	687.8	77.4	94.3	79.7	1,469	401	204.8	106.7	99.4	119.5	110.4	116.3
1971 [5]	869.4	1,046.8	629.9	741.3	82.8	108.6	81.5	2,081	492	207.0	106.5	98.7	116.7	113.9	121.3

[1] 1967 dollars calculated by Forest Service, except "Expenditures for new construction," 1969–71.
[2] Manufacturers' shipments.
[3] As of July 1.
[4] Index for city wage earners and clerical workers.
[5] Preliminary.

Source: Gross national product, disposable personal income, and expenditures for new plant and equipment, Council of Economic Advisers, 1950–59, "Economic Report of the President, "January 1972; 1960–71, "Economic indicators," February 1971. Expenditures for new construction, U.S. Department of Commerce, Bureau of the Census. "Value of new construction put in place," Construct. Reps. Ser. C30. Number of housing starts, U.S. Department of Commerce, Bureau of the Census. "Housing Starts," Construct. Reps. Ser. C20. Mobile homes, U.S. Department of Commerce, Bureau of Domestic Commerce. "Construction review," Monthly Indust. Rep. Population, U.S. Department of Commerce, Bureau of the Census. "Population estimates and projections." Curr. Pop Reps. Ser. P-25. Index of industrial production 1954–70, Board of Governors of the Federal Reserve System. "Detailed industrial production series, January 1954–March 1971," 1971 revision; 1971, U.S. Department of Commerce, Bureau of Economic Analysis, "Survey of Current Business". Wholesale price index, U.S. Department of Labor, Bureau of Labor Statistics. "Wholesale prices and price indexes". Consumer price index, U.S. Department of Labor, Bureau of Labor Statistics. "The consumer price index".

Production, imports, exports, and apparent domestic

[Million cubic feet,

Year	All products: Domestic production	All products: Apparent consumption	Industrial roundwood used for— Total: Domestic production	Total: Imports	Total: Exports	Total: Apparent consumption	Lumber: Domestic production	Lumber: Imports	Lumber: Exports	Lumber: Apparent consumption
1950	10,795	12,180	8,525	1,525	140	9,910	5,905	535	80	6,360
1951	10,970	12,180	8,740	1,465	260	9,950	5,780	395	155	6,020
1952	10,780	11,940	8,775	1,375	215	9,935	5,820	390	115	6,095
1953	10,710	11,940	8,790	1,420	190	10,020	5,710	430	100	6,040
1954	10,585	11,780	8,750	1,460	270	9,945	5,635	480	115	6,000
1955	10,950	12,220	9,205	1,610	335	10,475	5,785	560	130	6,215
1956	11,280	12,615	9,625	1,645	310	10,960	5,920	535	120	6,335
1957	10,190	11,345	8,625	1,490	335	9,780	5,100	465	130	5,435
1958	9,985	11,170	8,505	1,495	310	9,690	5,160	530	115	5,575
1959	10,750	12,095	9,360	1,700	355	10,705	5,745	635	125	6,255
1960	10,210	11,435	8,910	1,680	455	10,135	5,080	615	135	5,560
1961	9,940	11,185	8,725	1,745	495	9,970	4,945	665	120	5,485
1962	10,155	11,570	9,035	1,910	500	10,445	5,120	765	120	5,765
1963	10,615	11,980	9,560	1,990	630	10,925	5,355	830	135	6,050
1964	11,175	12,495	10,190	2,040	720	11,510	5,635	815	150	6,305
1965	11,465	12,850	10,550	2,105	715	11,935	5,670	815	145	6,345
1966	11,525	12,950	10,680	2,225	800	12,105	5,645	810	160	6,295
1967	11,215	12,420	10,440	2,160	955	11,645	5,360	800	175	5,990
1968	11,685	12,960	10,985	2,395	1,120	12,260	5,630	960	180	6,405
1969 [5]	11,565	12,930	10,945	2,500	1,135	12,310	5,535	980	180	6,340
1970 [5]	11,520	12,580	10,980	2,410	1,350	12,040	5,315	955	200	6,070
1971 [5]	11,960	13,520	11,460	2,735	1,170	13,020	5,695	1,185	170	6,710

[1] Columns may not add to totals because of rounding.
[2] Includes both pulpwood and the pulpwood equivalent of wood pulp, paper and board.
[3] Includes cooperage logs, poles and piling, fenceposts, hewn ties, round mine timbers, box bolts, excelsior bolts, chemical wood, shingle bolts, and miscellaneous items.
[4] Less than 2.5 million cubic feet.
[5] Preliminary estimates.

Sources: Based on data published by the U.S. Departments of Commerce and Agriculture. Data for 1900–49 in "The demand price situation for forest products, 1964," table 2.

consumption of timber products, by major product, 1950–71 [1]

roundwood equivalent]

Industrial roundwood used for—Continued												
Plywood and veneer				Pulp products				Miscellaneous products,[3] apparent consumption	Logs		Fuelwood, apparent consumption
Domestic production	Imports	Exports	Apparent consumption	Domestic production	Imports [2]	Exports [2]	Apparent consumption		Imports	Exports	
345	5	(4)	350	1,500	935	50	2,385	770	45	10	2,270
390	10	(4)	400	1,825	1,025	90	2,765	730	35	15	2,230
435	10	(4)	440	1,810	945	85	2,665	700	30	10	2,010
475	15	(4)	495	1,910	[illegible]	70	2,775	675	40	20	1,920
480	30	(4)	505	1,960	920	135	2,745	555	35	25	1,835
575	40	(4)	615	2,185	975	175	2,980	630	35	25	1,745
590	45	(4)	630	2,480	1,040	160	3,355	605	30	30	1,655
560	45	(4)	605	2,360	960	185	3,135	580	25	25	1,565
615	50	(4)	665	2,135	895	165	2,870	560	15	30	1,480
720	75	5	790	2,330	970	195	3,105	555	20	35	1,390
705	60	(4)	765	2,565	985	275	3,280	510	20	45	1,300
765	60	(4)	825	2,450	1,000	295	3,155	490	20	75	1,215
800	75	(4)	875	2,565	1,055	295	3,325	465	20	85	1,125
870	80	5	950	2,670	1,060	340	3,390	515	15	150	1,055
960	90	5	1,045	2,885	1,120	395	3,610	540	10	170	985
1,030	100	5	1,125	3,100	1,175	380	3,900	560	10	190	915
1,030	115	5	1,140	3,220	1,285	420	4,085	565	15	220	845
1,030	110	10	1,130	3,220	1,235	460	3,995	515	15	310	775
1,060	165	10	1,210	3,410	1,260	525	4,140	485	15	405	700
960	180	20	1,120	3,620	1,330	565	4,385	455	15	375	620
995	170	15	1,145	3,815	1,265	700	4,375	425	25	430	540
1,130	210	15	1,320	3,825	1,325	625	4,525	450	15	360	500

Glass containers

[In thousands of gross]

Year	Manufacturers shipments	Imports	Exports	Apparent consumption
1951	114, 738	(1)	(1)	(1)
1952	114, 102	(1)	(1)	(1)
1953	127, 516	(1)	(1)	(1)
1954	124, 649	(1)	(1)	(1)
1955	137, 278	(1)	(1)	(1)
1956	140, 890	(1)	(1)	(1)
1957	143, 467	(1)	(1)	(1)
1958	143, 366	(1)	(1)	(1)
1959	153, 102	(1)	(1)	(1)
1960	156, 799	(1)	(1)	(1)
1961	165, 656	(1)	(1)	(1)
1962	174, 195	(1)	(1)	(1)
1963	177, 886	(1)	(1)	(1)
1964	186, 741	205	(1)	(1)
1965	198, 131	240	17, 359	181, 012
1966	206, 299	393	19, 568	187, 124
1967	231, 046	385	8, 792	222, 639
1968	223, 635	980	2, 960	221, 655
1969	253, 198	1, 243	3, 475	250, 966
1970	266, 610	1, 098	3, 796	263, 912

[1] Comparable unit data not available for years indicated.

Natural rubber

[Long tons]

Year	Imports	Exports	Stockpile sales [1]	Consumption
1951	743, 048	2, 603		454, 015
1952	805, 575	3, 024		453, 846
1953	647, 614	8, 376		553, 473
1954	597, 200	7, 443		596, 285
1955	637, 577	10, 611		634, 800
1956	579, 217	11, 302		562, 088
1957	553, 672	10, 146		538, 761
1958	474, 409	16, 749		484, 492
1959	573, 467	16, 265	6, 786	555, 044
1960	410, 767	12, 410	88, 937	479, 048
1961	390, 907	6, 036	25, 770	427, 341
1962	421, 096	8, 159	56, 097	462, 759
1963	379, 527	17, 814	84, 191	457, 228
1964	441, 763	29, 135	95, 974	481, 500
1965	446, 230	36, 533	119, 660	514, 706
1966	432, 318	49, 836	156, 608	545, 678
1967	453, 524	41, 220	96, 884	488, 848
1968	540, 570	40, 923	78, 615	581, 864
1969	585, 632	23, 070	34, 762	598, 272
1970	550, 268	15, 988	25, 528	559, 315

[1] Stockpile acquisitions took place primarily in the 1950–53 period but annual data are not available.

Plastics materials and resins

[Million pounds]

Year	Production [1]	Imports [2]	Exports [2]	Apparent consumption
1951	2, 441	9	199	2, 251
1952	2, 333	10	173	2, 170
1953	2, 777	21	199	2, 599
1954	2, 828	20	254	2, 594
1955	3, 739	24	324	3, 439
1956	3, 977	30	423	3, 584
1957	4, 340	26	509	3, 857
1958	4, 518	26	583	3, 961
1959	5, 865	36	718	5, 183
1960	6, 143	40	819	5, 364
1961	6, 710	29	862	5, 877
1962	7, 942	34	918	7, 058
1963	8, 968	56	930	8, 094
1964	10, 103	43	1, 247	8, 899
1965	11, 685	58	1, 213	10, 530
1966	13, 585	148	1, 033	12, 700
1967	13, 793	178	1, 077	12, 894
1968	16, 360	219	1, 503	15, 076
1969	18, 676	242	1, 547	17, 371
1970	19, 172	278	1, 635	17, 815

[1] U.S. Tariff Commission.
[2] Bureau of the Census and BDC estimates.

Synthetic rubber

[Long tons]

Year	Production	Imports	Exports	Consumption
1951	845, 159	10, 085	9, 249	758, 897
1952	798, 566	19, 891	22, 101	807, 037
1953	848, 441	12, 780	22, 668	784, 836
1954	622, 852	16, 901	30, 117	636, 727
1955	970, 468	10, 529	93, 734	894, 899
1956	1, 079, 574	7, 767	149, 368	874, 394
1957	1, 118, 173	6, 828	203, 448	925, 879
1958	1, 054, 625	9, 300	193, 917	879, 912
1959	1, 379, 652	6, 719	290, 468	1, 072, 726
1960	1, 436, 442	9, 195	341, 954	1, 079, 245
1961	1, 404, 009	11, 660	296, 983	1, 102, 171
1962	1, 574, 464	13, 508	303, 903	1, 255, 936
1963	1, 608, 453	18, 860	283, 404	1, 306, 786
1964	1, 764, 941	31, 926	321, 257	1, 451, 513
1965	1, 813, 232	39, 993	282, 560	1, 540, 114
1966	1, 969, 973	44, 510	308, 535	1, 666, 057
1967	1, 911, 873	40, 506	303, 169	1, 628, 258
1968	2, 131, 105	60, 808	292, 562	1, 896, 200
1969	2, 250, 192	79, 348	231, 529	2, 024, 061
1970	2, 197, 004	92, 261	298, 736	1, 917, 852

Reclaimed rubber

[Long tons]

Year	Production	Imports	Exports	Consumption
1951	365, 933	767	14, 744	346, 121
1952	273, 386	1, 595	11, 180	280, 002
1953	295, 550	2, 787	11, 597	285, 050
1954	257, 088	1, 013	10, 232	249, 049
1955	325, 914	734	13, 988	312, 781
1956	286, 804	416	13, 832	270, 547
1957	273, 989	158	13, 025	266, 852
1958	259, 578	231	11, 362	248, 156
1959	304, 145	136	13, 027	290, 410
1960	292, 796	407	13, 759	276, 515
1961	263, 860	25	15, 520	250, 285
1962	280, 527	361	17, 557	263, 419
1963	281, 449	500	17, 412	263, 668
1964	276, 257	785	15, 491	263, 194
1965	280, 289	1, 084	10, 965	269, 542
1966	277, 363	1, 265	11, 559	264, 506
1967	243, 650	1, 868	9, 909	239, 271
1968	257, 218	4, 204	9, 750	250, 426
1969	238, 923	1, 970	9, 188	231, 770
1970	200, 555	1, 586	9, 240	199, 571

ELEMENTS OF A NATIONAL MATERIALS POLICY

NATIONAL MATERIALS ADVISORY BOARD

DIVISION OF ENGINEERING - NATIONAL RESEARCH COUNCIL

Publication NMAB 294

National Academy of Sciences - National Academy of Engineering

2101 Constitution Avenue

Washington, D. C. 20418

August 1972

NOTICE

The study reported herein was undertaken under the aegis of the National Research Council with the express approval of the Governing Board of the NRC. Such approval indicated that the Board considered that the problem is of national significance; that elucidation or solution of the problem required scientific or technical competence and that the resources of NRC were particularly suitable to the conduct of the project. The institutional responsibilities of the NRC were then discharged in the following manner:

The members of the study committee were selected for their individual scholarly competence and judgment with due consideration for the balance and the breadth of disciplines. Responsibility for all aspects of this report rests with the study committee, to whom sincere appreciation is expressed.

Although the reports of our study committees are not submitted for approval to the Academy membership or to the Council, each report is reviewed by a second group of appropriately qualified individuals according to procedures established and monitored by the Academy's Report Review Committee. Such reviews are intended to determine, inter alia, whether the major questions and relevant points of view have been addressed and whether the reported findings, conclusions, and recommendations arose from the available data and information. Distribution of the report is approved, by the President, only after satisfactory completion of this review process.

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PREFACE

This report replies to a request from the National Commission on Materials Policy for early identification of issues and problems to whose resolution a national materials policy should be directed, and to recommend such possible solutions, constructive actions, and needed studies as could be reasonably formulated within the time allowed.

The limitations of our inquiry were fixed by the time available between receipt of charges and the deadline date for the report. We met on the 13th of April to define the central issues and identify persons qualified and available to serve on affiliated study panels. We met again on the 19th and 20th of May to engage in seven simultaneous panel workshops (19th of May only), and to discuss in plenary session the panel contributions (morning of 20th of May), and rough out the final report (afternoon of 20th of May). The rest of our work was done by mail and telephone. By direction or necessity, we have confined our consideration to mineral materials excluding water, and have considered these primarily in general terms except by way of exemplification or as specific issues arose.

Thus our responses are not the fruits of long deliberation together and they do not cover all fields of materials science and engineering. Rather they represent the pooled

judgments of several groups of people who have been concerned about questions and issues believed central to the formulation of a coherent and workable materials policy, and who were willing to interact with other groups and respond to their criticisms, all on short notice. Because of the way it was put together, the style of this report is inevitably uneven; but we have tried to confront the issues squarely and to respond to them honestly. While we are painfully aware that more time would have produced a smoother and more balanced report, we hope we have come close to our goal of identifying a substantial number of the significant elements involved in the formulation of a national, or even an international, materials policy.

Finally, it must be added that this report presents the consensus of a diverse group with backgrounds in industry, government, and academia. It is unlikely that any participant is in agreement with all statements in the report. It is interesting, nevertheless, that there was but small support for the view that market forces alone will solve the foreseeable problems. Even in the areas in which there was complete agreement, more extensive study will be essential to the formulation of a truly comprehensive and durable national materials policy.

PRESTON CLOUD, Chairman
Ad Hoc Committee on
Materials Policy

ABSTRACT

Seven major issue areas are considered as central to the formulation of a coherent and durable national materials policy. They are:

1. Abundances of mineral commodities and problems affecting future primary supplies
2. Implications of environmental protection policy for national materials policy
3. Recycling, substitution, synthesis, and design
4. Extractive metallurgy and mineral processing
5. Governmental incentives and controls
6. International implications of materials policy issues
7. Manpower and facilities

The issue areas are the subject of separate skeletal chapters representing the pooled views of special panels convened to identify, in their bare essentials, the more explicit issues and problems connected with their respective areas. Demographic, economic, environmental, educational, and international issues and variables are considered as appropriate to the content of all chapters even though these were in part the major charges of individual panels.

Crucial to all seven issues is an eighth one, not the subject of separate study -- the continuing growth of populations

and demands for materials. Any viable materials policy must recognize and cope with the pressures created by increasing per capita consumption of materials, increasing numbers of consumers, and growing need for control of both.

CONTENTS

SUMMARY

The maintenance of a healthy and moral industrial society depends on a continuing and varied flow of raw and refined materials, obtained and processed with due regard to environmental quality and for fundamental equity among people and nations. The United States and the world in general are at a point of growing pressure with respect to availability of raw materials, their harmonious apportionment among nations and social groups, and the impact on our ecosystem and society of their production, refinement, and disposal.

Study of a selected group of key mineral raw materials over recent decades by E. N. Cameron of this Committee, reveals that domestic production in the United States has decreased from about 40 percent of world production in 1940 to less than 20 percent in 1971, and is still trending downward. We are now almost completely dependent on foreign sources for 22 of the 74 non-energy mineral commodities considered essential for a modern industrial society. The First Annual Report of the Secretary of the Interior under the Mining and Minerals Policy Act of 1970 (March 1972, Table 10, Fig. 11) shows that, across the board, in 1970, the United

States imported about 20 percent of its total primary mineral requirements, while using about 35 percent of the global mineral product. Meanwhile, consumption is pushed upward both by growing populations and by increasing per capita demands. It escalates in such a way under these pressures that, even with substantially enlarged domestic production and recycling, an end-of-century deficit of 54 percent of our primary raw materials demand is forecast in the Secretary's report. Thus our dependence on imports is growing, and at the very time that general world demand has also begun to rise more rapidly, foreign sources grow increasingly precarious, and "Third World" voices for an equitable share in Earth's material goods grow ever more insistent. The trends are explicit in the graphs, tables, and commodity summaries of the report referred to, as well as in the "Interim Report" of April 1972 by the National Commission on Materials Policy.

It is clear that a fresh and flexible materials policy must be formulated and continue to evolve if we are to cope with present challenges and expected changes. The concept of continuing <u>material</u> growth as an axiom and keystone of such a policy needs to be re-examined, particularly where it does not demonstrably add to quality of life in terms of variety and flexibility of options for living generations and avoidance of their foreclosure for future ones. Environmental, social, and energy costs must be counted, along with obvious fiscal costs, as the total price we pay for continuing material affluence. Perceptive and sustained attention must be paid to the net of interactions among all the varied

activities having to do with the supply of finished materials of specified characteristics for structures and functions. Similar attention is needed to the provision and training of the scientists and technologists required to conduct these activities and to safeguard the ecosystem, as well as to the effectiveness of the facilities with which they work.

The crux of the matter is how to sustain a continuing flow of needed raw materials without encountering unacceptable environmental, social, political, or fiscal costs. Mineral industry issues central to needed solutions are summarized below and briefly elaborated in Chapters 1 to 7.

Although some mineral commodities are widespread and abundant, others, relatively abundant, are unevenly distributed, and still others are rare and geographically limited. We should try, as far as possible, to base our industrial future on widespread and abundant basic commodities, such as iron, aluminum, magnesium, and the silicates, and to minimize dependence on those in short supply. And we should create or strengthen the institutions and support the research needed to evaluate and monitor the complete spectrum of mineral supplies and demands on a continuing basis.

Environmental costs of materials supply, already severe, will increase still further in the absence of firm and continuing precautions, and perhaps even with them. To produce, fabricate, and dispose of wastes from ever larger quantities of

metals obtained from ever leaner deposits demands ever larger investments of energy and creates growing potential for damage to all aspects of our environment on, above, and below the land surface, including living organisms. Conservational measures are needed, not only to stretch our resources but to restore, protect, and perpetuate a livable human habitat. The numbers of humans occupying that habitat, moreover, must be limited to numbers it can comfortably sustain and their individual consumptions of materials must be kept within supportable limits.

Recycling, substitution, synthesis, and efficient design are conserving measures that also can contribute to alleviation of environmental problems. But much research is needed in these fields, and no panaceas are in sight. Recycling also requires substantial use of energy. And none of these conserving measures can be sustained indefinitely with exponentially growing material demands -- especially where doubling times get shorter and the quantities doubled grow ever larger. Materials- and energy-consuming per capita demands of the already affluent, therefore, must level off if more equitable distribution of material wealth is to be achieved, environment protected, and unavoidable population increases sustained -- even at the minimal levels programmed by bare replacement growth of societies with existing age structures. Creation of new composite materials or synthesis from abundant commodities that can substitute for those in short supply should

be vigorously encouraged, as should more efficient design. But synthesis cuts two ways -- conserving some things at the expense of others -- and synthetic materials are sometimes more difficult to recycle or dispose of than natural ones.

Forest products are not discussed here, but, under proper management, they are obvious and renewable substitutes for mineral materials in various applications and must not be omitted from any comprehensive materials policy. Water (like air) is also an essential critical material that this Committee did not consider -- not because the problems are not vast, but because, on the whole, they are better understood than those of mineral resources, and they lie beyond the charges to and expertise of our members.

Extractive metallurgy and mineral processing are, in general, static arts that must be rejuvenated and expanded if the challenge of increased production from lower-grade materials, reduction of waste and pollution, and the fabrication of better products are to be accomplished. Educational support in these areas and in advanced and novel underground mining methods are major identifiable needs.

Appropriate governmental incentives and controls in many areas could promote the general goal of assuring a continuing flow of essential mineral raw materials. Such incentives and controls should be so designed and applied that, while they increase the general output, they also decrease waste and reduce the rate of increase in consumption toward

demand levels that can be met over the long term without hazard to the environment and without prejudicing greater material equity throughout the world. A variety of possible incentives and controls should be evaluated and analyzed as to goals and tradeoffs before choosing the preferred ones for the desired ends.

The international implications of materials policy issues are extensive, and interdependence is increasing. This nation must proceed with great care in order simultaneously to assure its own material necessities, encourage harmonious and more equitable distribution of Earth's raw and finished materials, and avoid or minimize environmental problems on a global scale. A permanent, representative Minerals Advisory Council, responsive to public, executive, and legislative needs, should be organized to evaluate, monitor, and keep under review not only national but also international reserves, demands, agreements, and policies relating to such matters.

Manpower and facilities are central to all other aspects of materials policy. However, we know little about them other than that the needs are great and many of the data unreliable or in dispute. Special continuing studies should be made of these matters. All we can say with confidence is that available manpower is inadequate to the task and that domestic facilities in some important fields are outmoded as compared with those in other advanced countries. Industry and government should cooperate in over-

coming these deficiencies.

Finally, it is clear that the difficulties imposed by growing U. S. and world populations pervade all other issues, and that there can be no effective national or international materials policy that evades this crucial variable or fails to couple it with the equally pressing and related problems of increasing per capita demand and environmental impact.

Chapter I

ABUNDANCES OF MINERAL COMMODITIES AND PROBLEMS AFFECTING FUTURE PRIMARY SUPPLIES

Here we consider the abundances of groups of commodities essential to the industrial economies of the United States and the world, and develop issues involved in ensuring adequate supplies of these minerals to the United States. Certain premises underlie the discussion that follows, which we hold to be either the inevitable consequences of available data, or to be self-evident.

1. The United States cannot maintain its present standard of living without large-scale use of mineral commodities.
2. Domestic supplies of mineral commodities, actual and potential, are not adequate to support unlimited increase in scale of use -- a much ignored truism.
3. Given the prospect of increasing competition for the world's raw materials, the United States should attempt to slow its trend toward increasing dependence on foreign sources. We agree unanimously, however, that even if complete self-sufficiency were selected as a desirable goal, it is unattainable in terms of (a) actual or potential supplies of minerals from domestic sources and (b) present U. S. industrial technology.

4. The problem of United States mineral supply is a threefold one of
   a) maximizing discovery and environmentally and socially responsible development of long-term competitive domestic sources of minerals;
   b) adjustment of technology over a period of time to available primary and secondary resources, so far as is technically and economically feasible; and
   c) assurance of supplies of other essential minerals from foreign sources.
5. Environmental, social, and political consequences of efforts aimed at improving U. S. mineral supply must be acceptable in this country and in the broader community of nations.

AVAILABILITY OF MINERAL COMMODITIES

Mineral commodities vary so widely in their crustal abundances, types of deposits, and geographic distribution that no general statement regarding their production and availability can be made. We have, therefore, grouped them into three general categories and subdivided the three categories on the basis of present or readily attainable self-sufficiency for the United States.

A. <u>Commodities that are abundant and widely available globally</u>

One important group of commodities is widespread and

abundant on a global scale. We believe that critical shortages of such commodities are not likely now or ever in a rational world. For a number of these commodities, the United States is already self-sufficient, and production could proceed for many generations without technological changes. Typical examples are salt, cement, crushed stone, and building stone.

Certain commodities already imported by the United States to a greater or less degree also belong in this category because domestic resources available could be successfully worked at somewhat higher costs. Typical examples are production of iron from low-grade ores, aluminum from clays and other non-bauxite sources, and titanium compounds from low-grade ilmenite deposits. Energy requirements and environmental considerations in certain instances, however, may set serious limitations on use of such resources.

For each of these commodities the United States could be self-sufficient. The decision for or against such a position with respect to any commodity is largely a tactical-economic one. Alternate foreign sources of some are expensive. The capability of internal production, however, serves to set a price ceiling and hence to restrain price control by foreign suppliers.

B. <u>Commodities that are relatively abundant but unevenly distributed on a geographic basis</u>:

For a second group of mineral commodities, identified reserves, reasonably expectable discoveries using existing

technology, and, to some extent, small price rises can guarantee a stable global production at least for several generations, and probably longer. These commodities, however, are not distributed evenly across the earth. We therefore divide them into two subcategories:

1) Commodities that are abundant in the United States and for which present or future self-sufficiency has already been achieved or would probably be possible in the future. Examples are molybdenum, potash, phosphate, coal, and possibly copper and lead. Should breeder technology be developed, uranium and thorium could be added to the list.

2) Commodities in which the United States is deficient compared with demand, and for which we believe only a small probability exists that exploration, price changes, and technological advances will allow self-sufficiency to develop. Examples are manganese, chromium, nickel, fluorspar, niobium, and hydrocarbons other than coal.

C. Commodities that are intrinsically rare and also geographically restricted:

Crustal abundances set ultimate limits on availability of certain commodities in terms of foreseeable technology. Excluding such changes as reduction in energy costs by one or two orders of magnitude, it seems unlikely that geochemically scarce elements or compounds will be recovered from

average rocks and minerals. Even with a reduction in energy costs, and even if unlimited energy becomes available, it is unlikely that average rocks could be processed without disastrous environmental consequences. We subdivide this category into two subcategories:

1) Commodities in which the United States is self-sufficient on a continuing basis. Cerium metals and boron fall in this group, but examples are distressingly rare.

2) Commodities in which the United States is deficient. Examples are platinum, gold, mercury, tin, and tantalum.

We recognize that for many of the intrinsically rare commodities, present knowledge of processes controlling the formation and distribution of deposits is inadequate. Although research and exploration may change the situation with respect to some of these commodities, we do not believe it likely that discoveries will move a commodity from Group C (intrinsically rare and geographically restricted) into Group B. And it is virtually certain that no commodities will move from Group C or Group B to Group A (abundant and widely available).

CENTRAL ISSUES AND THEIR RESOLUTION

The future availability of essential mineral commodities to the United States will depend on the resolution of

four basic issues. These are stated as questions below, followed by the panel's responses.

Question I: What steps must be taken to ensure maximum utilization of domestic mineral resources without unacceptable damage to the environment?

Response:

1. An adequate information base must be provided by means of

   a. Completing the geological, geophysical, and metallogenic mapping of the United States in order to provide the essential foundation for effective exploration and discovery of domestic mineral resources.

   b. Definitive studies of the origins, habits, and distribution of mineral deposits.

   c. Definition of geological environments in which mineral deposits have preferentially formed in the earth's crust.

   d. Identification on the basis of a, b, and c of mineral provinces in which yet undiscovered mineral deposits may be found, including deeply buried or otherwise concealed ore bodies.

   e. Geophysical and geochemical studies of mineral provinces and districts to facilitate exploration and discovery.

   f. Establishment of a central information bank on the

above. Statistical data should likewise be available from this bank.

2. Land available and desirable for mineral exploration must be delimited. The amount of land open to mineral exploration in the United States has decreased drastically. The lands on which exploration activities are limited or prohibited can be characterized as follows:
   a. Areas precluding any multiple land use, such as military reservations and testing grounds, parks, and wilderness areas;
   b. Areas permitting some multiple use, such as towns, cities, and highway rights of way; and
   c. Areas for which there exist conflicts in popular attitude toward their use, such as some federal, state, or county lands not made available for exploration out of concern for environmental impact.

   Classification of lands with respect to mineral potential is essential as a basis for determining what land areas should be held open for mineral exploration and mining and which should be reserved for other purposes. Potential environmental damage and means of controlling and minimizing it, as well as of restoring quality where inadvertent damage occurs, must be given top priority at all levels of land classification, mineral exploration, mining, and other phases of materials exploitation and development.

There are, in addition, large areas with mineral producing potential that could be made available for exploration if questions of legal tenure could be clarified. Examples are the continental shelves (especially for petroleum and natural gas) and the deeper sea floors (for phosphate and for Ni, Cu, and Co in "manganese" nodules). Jurisdiction within such areas must be clarified as to appropriate state, national, or international agencies, and appropriate environmental guidelines must be developed before exploration and development can proceed without undue legal and environmental hazards.

3. Improved and new cost-efficient techniques for detecting and sampling mineral deposits must be developed. New domestic deposits will be found in increasing proportion at depth under barren rock. Research on and development of exploration techniques are essential.

4. Current mining techniques must be improved and new mining techniques must be developed. Research and development toward these ends is needed in order to develop low-grade materials and deep deposits efficiently and with due regard to environmental quality. Research and development are especially needed for new and better methods of underground mining, taking advantage of opportunities for communication with those concerned with rock mechanics and with development of

more efficient and more rapid means of surface and subsurface excavation. Underground mining is potentially much less damaging to the environment than surface mining, although it poses greater safety hazards and entails greater monetary costs.

Question II: To what extent can domestic mineral deficiencies be alleviated by eliminating non-essential uses of minerals and building more durable machines, structures, and components?

Response:

We believe that more conserving practices are now strongly advisable and will become essential. At the same time we recognize that many little-understood interactions are involved and that pressures are greater on some commodities than on others. Time, a better understanding of the interactions, and economic adjustments will all be needed to achieve the necessary conversions smoothly. We recognize that the implementation of such measures as are now clearly practicable should be supplemented by a careful study of the complexities and trade-offs, with a view to arriving at more explicit and more orderly recommendations for further actions.

Question III: To what extent can domestic mineral deficiencies be made less critical by adjusting industrial technology to resources available within the United States or, alternatively, North America?

Response:

The seriousness of domestic mineral deficiences can be substantially reduced by efforts directed toward the following:

1. Shifting technology, over a period of years, toward the use of more abundant mineral commodities, shifts being geared to obsolescence of exising mining, beneficiation, metallurgical, and manufacturing facilities.
2. Eliminating non-essential uses and planned obsolescence.
3. Research on extraction from low-grade materials.
4. Research on extraction of useful materials from wastes of present mining operations.
5. Standardizing products as an aid to design and reclamation.
6. Using abundant materials that are not yet as widely used as they could be (e.g., silicates).

Two phases of activity are required: (1) study of industrial technology to identify sectors of industry in which use of one or more of the above might help to offset mineral deficiencies, and (2) research and development in alternative technology.

We stress also the great importance of any steps that may be taken to improve efficiency of recycling mineral materials -- a subject discussed separately in Chapter III.

We believe that planned adjustment of technology to available domestic resources is essential. The alter-

native is progressive deterioration in the mineral position of the United States, with all that that implies. One can foresee, within decades, failing such an adjustment, the erosion of United States mining, smelting, refining, and mineral-based manufacturing industries, growing economic colonialism, international frictions, a steadily deteriorating balance of trade, and a tarnished global image of the nation. Government encouragement of needed transitions through sponsorship of research in materials design and use, as well as through tax and other incentives, will probably be essential.

Question IV: How can the United States be assured of supplies of minerals in which it is deficient from foreign sources?

Response:

There can be no firm long-term assurance. Nevertheless, every effort should be made to develop equitable long-term agreements or mechanisms for exchange of commodities, mineral or otherwise, in which the United States is deficient.

Resources in categories A, B(1), and C(1) are or could be sources of exportable surpluses that could be exchanged for minerals in categories B(2) and C(2), either through arrangements by private industry, by agreements between the United States and other nations, or by combinations of both. In view of the increasing

international competition for mineral raw products, specific formal arrangements may be essential to assure adequate supplies. Such arrangements seem particularly necessary to assure supplies of minerals in category C(2), for which neither domestic production nor relief through substitution or technological adjustments seems likely.

It should be noted that for intrinsically rare and geographically restricted mineral commodities (Group C) there is the possibility of global exhaustion of resources, in some cases within a century or less. Helium, natural gas, mercury, and gold are in this category. Conservation on an international scale will be needed, and it is not too soon to begin thinking about an international body that might be created for this purpose. In this connection it is well to bear in mind that stockpiling is not a conservation measure but an emergency palliative and an implement of price control. To the extent that it is undertaken it should be done with those goals and limitations in mind.

Chapter II

IMPLICATIONS OF ENVIRONMENTAL PROTECTION POLICY FOR NATIONAL MATERIALS POLICY

The National Environmental Policy Act (NEPA) of 1970 was enacted because "The Congress, recognizing the profound impact of man's activities on the interrelations of all components of the natural environment, particularly the profound influences of population growth, high density urbanization, industrial expansion, resource exploitation, and new and expanding technological advances and recognizing further the critical importance of restoring and maintaining environmental quality -- (wished) to create conditions under which man and nature can exist in productive harmony, and fulfill the social, economic, and other requirements of present and future generations of Americans" (emphasis ours).

In this Chapter we consider the implications of the NEPA for the formulation of a national materials policy that seeks to respond constructively to the charge that it "enhance environmental quality." Can a realistic and acceptable national materials policy be formulated given the constraints of the NEPA? Is the NEPA realistic, given the assumption that the free enterprise system and an equal or increasing per capita use of resources will continue to be desired by the majority of Americans? If the existing NEPA

and currently accepted materials development procedures are found to be incompatible, can we recommend environmentally acceptable changes in the NEPA?

Projections of U. S. mine production, imports, and indigenous demands are shown graphically for several minerals in "An Interim Report" by the National Commission on Materials Policy (April 1972). The relationships portrayed in many of these curves reflect and underscore the issues. That is, the national demand for many critical minerals will increase during the next three decades while domestic production, even assuming new discoveries and more efficient recovery procedures and reuse, will supply ever smaller fractions of the total demand. It further seems clear that the projected increases in demand will be caused both by continuing population growth and increasing per capita consumption. The predicted divergence between domestic supply and total demand will be partially reduced by increasing imports as well as by the development of more efficient technological procedures.

If the trends portrayed are realistic, and are not improved by corrective action, the nation will, over the next decades, become increasingly dependent on foreign mineral resources, while, at the same time, it will have to strive harder to produce more of its domestic needs from ever leaner ores. Thus, there will be both increasing opportunity for international conflict and likelihood of increasing

destructive environmental consequences. In a broad view of environmental consequences, if it does become obvious that there are inadequate mineral resources to support the growing populations of the world at the desired standard of living, what measures will or should the United States adopt to limit its consumption or to assure the desired materials supply to our country?

Below we list selected critical issues, selected important research needs, and recommendations for research and education in resource use. Unfortunately, time did not suffice for the preparation of thoughtful written responses to all the questions we consider to be germane.

1. Environmental cost accounting:

   The cost of materials extraction must be made to include the cost of preventing or repairing environmental damage to living systems. The price of raw metals and other minerals under present methods and controls is a very small percentage of the GNP and could be doubled or tripled without major influence on the cost of manufactured articles. A problem to be worked out is how best to cope with non-domestic suppliers not operating under similar controls.

2. Damage from wastes:

   Damage to physical and biological systems from wastes must be recognized and minimized at every step from mine to ultimate user.

3. <u>Monitoring contaminants</u>:

Analytical capabilities need to be established and maintained at appropriate stations to monitor the levels of contaminants (e.g., Hg, As, Pb, Cd, Ni, Be, SO_2, asbestos) from materials-processing and from nature and to identify major sinks, sources, and flows in natural systems. An agency other than those responsible for developing resources and thus generating contaminants should be charged with this task. Thus, at present levels of development, AEC should not be responsible both for atomic energy sources and generation <u>and</u> for setting emission standards and controls, although that may have been an appropriate dual function when the only real technical expertise lay within AEC as a promotional agency. In such instances of embryonic technology, there should always be a planned and phased transition of regulatory responsibility from the promotional agency to an independent agency as the total body of available expertise allows.

4. <u>Finiteness of critical components of biologic systems</u>:

Among other depletable material resources, phosphorus is emphasized at this point because it is an essential resource for agriculture (as well as a pollutant of lakes) but is not cyclic within times of interest to man. Phosphorus is essential to all life, including the food we grow. As phosphates are both nonsubstitutable

and nonrenewable, it is essential to re-evaluate global resources and recycling of phosphates in an ecological context and to improve on the present highly inefficient use of phosphorus.

5. Environmental consequences of development of energy resources:

Although energy resources may be very large, unlimited development of energy resources would unacceptably increase existing problems of heat disposal, not to mention other environmental consequences such as noxious pollutants and solid-waste disposal problems. The safe and environmentally acceptable management and control of these consequences must be an integral part of future production.

6. Legal incentives for environmental management:

Legal responsibility must be established on a regional basis to assure continued biological and material productivity at sustainable levels, not growth of one at the expense of the other.

7. Environmental reclamation:

Biological productivity must be restored in areas that have in the past been degraded by materials extraction. Future disposal of mine and smelter wastes must be planned in advance to be consistent with ecological goals. Surface mining is a major source of land disturbance and potential contamination, especially

in large-volume operations such as strip-mining for coal and the open-pit mining of porphyry copper and low-grade iron ores. Particular attention should be paid to such operations.

8. <u>Compensation for environmental degradation or loss of employment due to materials production or non-production deemed essential to the general welfare</u>:

In order to reduce or prevent economic and other inequities as a consequence of national zoning policies, we should consider the evolution of plans whereby affected regions may be compensated for degradation of their environment because of exploitation considered necessary for the national welfare, or non-development for similar reasons. For example, coal mining in the Four Corners area benefits a large region as a power source to the detriment of local populations. In other areas local unemployment may result either from impairment of traditional enterprises or from deliberate failure to develop obvious new opportunities because of environmental or social tradeoffs seen as unacceptable.

9. <u>Global problems</u>:

In the long run means must be found to extend essential environmental restraints to the entire world. This vastly complex and increasingly urgent problem should be the subject of special study by a suitable mix of people.

10. Wilderness preservation:

It is essential to recognize the value of and to establish a global system of wilderness areas for baseline ecological studies, preservation of species and genotypes that may have future value, and for recreational and esthetic values. Such a system, however, should be established with due recognition of the potentialities of all candidate areas for future mineral production and the kinds of pressures and conflicts that may emerge as other sources are depleted.

RESEARCH NEEDS

1. Increased research is needed in ecosystem dynamics:

In particular a more detailed understanding is required of the physical, chemical, and biological processes that regulate the structure and function of ecosystems. Better unde standing of function will improve the sensitivity of predictive ecosystem models, which, in turn, will provide better evaluation of environmental implications of proposed materials policies and suggest needed modifications.

2. Multi-disciplinary research in ecosystem dynamics must be encouraged:

This will often require modification of existing institutional organization.

3. <u>Studies looking toward the recovery of ecosystems from past environmental mismanagement need support</u>:

Significant portions of the earth's surface show the effects of past exploitation. With projected increase in per capita consumption of materials and human population growth, we can expect that the number of such areas will increase. This is particularly true as we develop lower-grade ores. Examples of areas affected in the past include parts of Scotland deforested for fuel for iron smelting, and similar use of forests for smelting of copper in Cyprus and silver-gold ores in Nevada. Past and current ground disturbance and other environmental impact from surface mining for coal, copper, and iron provide more immediate illustrations of the problems.

ACTION RECOMMENDED

Deeper and broader understanding should be sought and communicated to the general public about alternatives in materials and environmental management, and their interactions, especially as concerns inherent and planned obsolescence of manufactured products and high rates of per capita consumption of raw materials. Major hazards confront us, not only in the depletion of specific key industrial materials, especially where not recycled, but also in

increased energy demands and thermal pollution even where recycling is practiced.

While we ourselves do not yet fully understand the issues and hence are unable to articulate them in specific quantitative and comprehensive terms, we are uneasily and acutely aware that current or increased doubling times of population growth and material consumption cannot be sustained and allow little reaction time after perception of impending crises.

The information now available to the public comes from a wide variety of differing or conflicting views, each of which tends to exhort rather than inform. Research and public information forums are needed to resolve or narrow the differences of view and inform the public about questions such as the materials and environmental costs of model obsolescence, product differentiation, and luxury products; and the affect of advertising on factors such as material consumption, product choice, conservation, and environmental protection. Better understanding and better communication is needed about the relative effects of population growth and per capita rates of consumption both in the United States and globally.

Chapter III

RECYCLING, SUBSTITUTION, SYNTHESIS, AND DESIGN

Recycling, substitution, synthesis, and appropriate design conserve raw materials and thus supplement primary resources. These practices may also result in other benefits, such as a reduction of pollution and of energy requirements relative to primary production. Such side effects, however, do not accrue automatically but require suitable planning. It is desirable in all cases that recycling, substitution, synthesis, and materials-oriented design should impose the fewest possible constraints on processing and service performance.

Recycling, substitution, synthesis, and materials-oriented design, in the absence of appropriate market forces, can be promoted by appropriate measures of public policy, such as subsidies or favorable taxation. Constructive public attitudes can contribute to the acceptance of recycled, substituted, or synthetic materials even if they involve some changes from the traditional expectations of consumers. In this way the general public can play a positive rôle, and the same holds for government agencies on all levels through their procurement policies.

It will be particularly important to induce business organizations to adopt practices designed to conserve materials. Incentives must be devised to turn decision-makers and designers in the direction of substitution, synthesis,

and materials-oriented design. Personnel in industry, as well as in government, will have to be made accountable for acting on such policies by more effective mechanisms than are now at hand. Attention to the requirements specified should become one of the criteria of performance in the same way that profitability, safety of operation, and others are now accepted as a basis for evaluating engineering design and performance. We recognize, of course, that the designer, engineer, and operator work within a framework of regulations, specifications, and conventions set by others, and that these often depend on such constraining factors as competitive pressures, tradeoffs, and consumer attitudes. Changes, therefore, need to be made in the policy-generating institutional and external spheres as well as at the operating level if operational decision-makers and designers are effectively to contribute to the activation of better practices in materials utilization and conservation.

Our more specific conclusions and recommendations are embodied in the following tabulation of issues, problems, needs, and opportunities.

GENERAL CONSIDERATIONS

The following general steps are held to be essential parts of the analysis of potentialities and problems in

recycling, substitution, synthesis, and design.

1. Materials-management problems should be critically evaluated on a continuing basis and priorities assigned with respect to
    (a) alleviation of projected shortages;
    (b) alleviation of environmental damage;
    (c) international considerations and national security.
2. Incentives should be designed and accountability established such that decision-makers and designers will be encouraged to pay more attention to recycling, substitution, synthesis, and design for materials conservation.
3. Policy alternatives that might achieve the same ends should be identified, compared, and evaluated: natural market forces, taxes, rationing, subsidies, and R & D incentives.
4. Existing governmental institutional arrangements for implementing conserving policies should be evaluated and appropriate changes made.
5. Before initiating research on any of the above, a separate, thorough assessment of the objectives of the research should be made in terms of hoped-for contributions to resource and environmental management, social goals, and conservation.

RECYCLING

1. Secondary materials recovery should be on at least as favorable a footing as primary materials production with regard to subsidies, taxation, and freight regulation.
2. Incentives for and constraints on the exploitation of economy-of-scale factors in recycling need examination, especially in fragmented industries and with regard to municipal waste disposal, where combined or pooled waste-management facilities might be made substantially more effective than individual treatment plants.
3. The relative costs in energy and pollution damage of secondary as compared with primary production should be evaluated in general and in particular, and instances should be identified in which more efficient recycling would reduce these costs.
4. Markets should be developed for materials derived from municipal waste.
5. Technology is required for recycling of high-priority materials in short supply and where normal market forces are not likely to respond in time.
6. Positive public attitudes toward recycled materials should be encouraged.
7. Government procurement policies favorable to the appropriate use of recycled materials would promote the establishment of volume markets.

8. The advisability of storing wastes (perhaps partly separated) for possible later recovery needs critical assessment.

SUBSTITUTION

1. Evaluation is needed of the conditions under which normal market forces will encourage substitution for specific critical materials and of the role of government regulation where market failure is probable.
2. Where available substitution for critical materials may degrade product performance, the development of new technology should be actively encouraged and the exchange of pertinent information promoted.
3. Search for substitutes should be encouraged wherever positive economic or environmental benefits might be achieved, as in improved product durability, disposability, or recyclability, or the elimination of toxic materials.
4. Government procurement and design policies favoring the appropriate use of non-critical substitute materials would help to demonstrate the practicability of the substitute materials.
5. In the case of essential but dissipative uses, the most abundant and least critical material that will do the job should be used.

6. Further emphasis should be placed on research on the processing and properties of relatively abundant metals and their alloys (such as aluminum, magnesium, iron), and on certain ceramics with the objective of substituting them for more critical materials. In such instances relative energy requirements and pollution effects should be taken into account.
7. The use of relatively abundant rather than less abundant materials should be encouraged wherever that is practicable.

SYNTHESIS

1. Replacement of critical natural materials by abundant and suitable synthetic materials should be encouraged where practicable.
2. Where potential synthetic materials clearly offer strategic, conservational, or environmental advantages over natural materials, research on and appropriate production of candidate materials should be encouraged.
3. The ecological advantages and disadvantages of natural materials as compared with possible synthetic substitutes need evaluation.

DESIGN

1. Innovation in materials application should be encouraged

to favor materials

(a) that are most abundant;

(b) that most efficiently meet a product's functional requirements;

(c) that improve product durability, maintainability, repairability, and recyclability.

2. Processing and fabricating methods should be encouraged that consume, waste, or disperse the least amount of materials for equivalent performance.
3. In selecting the specifications for a design, including material specification, standardization should be employed to promote maintainability, repairability, and recyclability.
4. The general goal should be a more conserving and more economical use of materials through better design.

The desired design criteria can best evolve from the precise knowledge of the properties and relative availabilities of materials. Thus, better integration is needed between mineral exploration and assessment, the extractive industries, and materials science and engineering, and all need both greater emphasis and more clearly focussed objectives.

Chapter IV

EXTRACTIVE METALLURGY AND MINERAL PROCESSING

The Interim Report of the National Commission on Materials Policy (April 1972) underscores the severe problems facing extractive metallurgy in the years ahead. The basic question is: How can we produce needed amounts of metals from ores of steadily decreasing grade while concurrently producing less environmental damage than in the past? The traditional processes by which our minerals are currently processed and metals extracted are no longer good enough. New and better processes must be developed. But how? What are the basic issues and how may we best move toward their resolution?

SOME PROBLEMS AND THEIR ALLEVIATION

1. Many of the process units of today's metal-extraction plants are obsolete. Replacing them with facilities capable of employing the best available technology would improve metal yields, reduce manpower demands, and clean up many of the environmental pollution problems caused by metal extraction. In many instances in private industry, the cash flow and profits after taxes have been insufficient to encourage replacement, considering the low return on the heavy investments required. How can we provide incentives and stimulation for replacement of these many obsolete process facilities?

2. Major energy inputs are required in all extractive metallurgy and mineral-processing operations. Some of these cause serious pollution. How can we reduce or eliminate the polluting processes and avoid inordinate increases in national energy requirements?

3. There are not enough extractive metallurgists and mineral engineers to design, build, and operate all the new, modern, and environmentally responsive plants that are now needed and will be required. Chapter VII deals with the broader issues of manpower and facilities, but the Committee as a whole agrees that the problem is especially severe in the fields of extractive metallurgy and mineral engineering and deserves re-emphasis here.

4. Problems presented by lower-grade ores require recognition that transformation of mineral deposits into mineral wealth grows increasingly dependent on improved technology. Some of this technology can be imported from abroad, but it must be supplemented and extended by a national effort in process research and development. The processing of waste materials to recover metals and other values must also be given high priority. The issue is: How can we maximize the appropriate utilization of our mineral resources?

5. National and international regulations are needed to effectively control pollution -- by an obvious extrapolation of government's historic mission of "law and

order." Redistribution of unwanted elements to atmosphere, water, and land (including its subsurface) is a normal consequence of minerals processing. Operations must be conducted in such a manner as to prevent or greatly minimize damage to health and welfare while concurrently conserving materials that might be put to good use. How can the government most expeditiously establish the required oversight?

6. The United States lags behind other industrial nations in the development and utilization of new and improved processes for metallurgical extractions. The results are lower recovery of metal values, higher process labor costs, and avoidable degradation of the environment. What can be done to alleviate these problems and reestablish leadership in such matters? Some steps required are as follows:

   (a) Wastes must be processed more extensively and more efficiently to recover metals and other values. Recycling of materials deserves high priority because of the joint contribution this makes to conservation of resources and reduction of pollution.

   (b) Improved methods of mineral recovery must be designed with the aim of conserving resources and reducing environmental damage through more efficient processing.

   (c) The effective processing of and extraction of metals

from lower-grade ore bodies will be required if world reserves are to be extended.

(d) Energy should be utilized more efficiently in the reduction of ores to metals. Processes that are wasteful of energy should be replaced by processes that are more energy conserving.

(e) Extraction processes that result in excessive use of materials and deter process improvement should be modified to conserve materials and encourage greater efficiency.

(f) The approaching depletion of clean, readily transportable, easy-to-use fuels such as natural gas warns of the need for processes to convert more abundant fuels (coal, oil shale, etc.) into cleaner and more convenient fuels.

As was made clear in the report of the Committee on Mineral Science and Technology (NAS, 1969),* neither the extractive industry nor the colleges of engineering are well prepared to face these challenges. Research and development on extractive processes in domestic industry have lagged behind foreign efforts in many instances. Extractive metallurgy in the schools has not had the support of federal grant money supplied to other engineering disciplines, and has either disappeared or has become a weak step-sister to physical metallurgy and materials science. These trends must be reversed if extractive metallurgy is to play an effective part in achieving the goals of Public Law 91-512.

*Mineral Science and Technology - Needs, Challenges and Opportunities; Report by the Committee on Mineral Science & Technology, NAS-NAE-NRC, Wash., D.C.,1969; 129 pp.

Needed, as soon as possible, is an ample and continuing supply of well-trained extractive metallurgists coming from modern training facilities. Without this, industry will continue to fall short in extractive-process development.

Selected examples of problems in extractive metallurgy requiring concentrated attention and action in industrial laboratories of the United States are:

1. Coke is a widely used fuel and reductant in metallurgical industries. Today's coke ovens are fast wearing out and must be replaced in kind or by a new process. It is doubtful that the conventional oven design can be satisfactorily modified to meet acceptable pollution standards. Some pilot plants are making "form" coke today, but more work is required to adapt this development to full-scale production.
2. Continuous reduction and refining processes from ore to molten metal are possible and are being developed in various foreign laboratories and pilot plants for steelmaking in France, England, the U.S.S.R., Australia, and probably Japan. Continuous copper-smelting work is also under way, but not in the United States.
3. Electric smelting, electrolytic reduction, hydrometallurgical operations, solvent extraction, pressure leaching, and fluid bed reduction are attractive alternates to the traditional pyro-metallurgical processes and should be intensively studied and more widely introduced.

4. Application of tonnage oxygen to smelting processes could facilitate the capture of sulfur dioxide for subsequent conversion to elemental sulfur or sulfuric acid and thus reduce SO_2 emissions.

RECOMMENDATIONS

Consideration of the above issues and challenges leads us to recommend the actions below:

1. The establishment of a National Minerals Processing Institute should be explored as a joint venture of industry, government, and the universities. Areas of investigation should include the mining and processing of all mineral resources as well as problems of environmental impact. New processes resulting from research sponsored by this institute should be made available to all by means of appropriate licensing procedures.
2. Present and planned activities of the U. S. Bureau of Mines should be reviewed with respect to research and development in extractive metallurgy and minerals processing and the monitoring of progress and problems in or related to these fields, including environmental consequences. To the extent necessary, additional funding should be provided and reorganization undertaken to assure that federal responsibilities in these areas are effectively met and that appropriate segments of the work are farmed out to educational institutions where

they could have a beneficial effect in reversing the decline in relevant advanced programs and student enrollments.

3. Policies for utilization of materials should be designed under constraints that will assure their best and most efficient use and conservation, including the most efficient utilization of all constituents of ores. Forecasts for materials and energy demands for the year 2000 (e.g., NCMP Interim Report, April 1972) indicate impending large increases in per capita consumption of many materials. Demand for aluminum, for example, is expected to increase about four-fold. Future demands for energy and certain other resources, and the degree of environmental impact, are directly related to the magnitude of the demands forecast. Projected increases in the use of aluminum, for example, would require large quantities of energy -- about twice the energy consumption of steel on an equivalent fabrication basis, or almost six to one on a weight basis. Thus the projected per capita increases should be critically analyzed as to urgency, feasibility, and desirability. Can they be justified across-the-board in an era of decreasing grade of primary mineral raw materials, growing dependence on foreign sources, and painful environmental impact, especially insofar as they do not contribute to the real quality of living in terms of enhanced variety and flexibility of options and a clean and healthful environment?

4. <u>Measures should be formulated and adopted leading to replacement of obsolete mineral-extraction facilities</u>. The ferrous and non-ferrous industries in the United States are operating with many obsolete plants that are inefficient in use of manpower, recover too low a percentage of the value content of the ores, and contribute seriously to air and water pollution. For the most part, the necessary scientific and engineering data are probably available for adequate design of modern plants that will meet pollution standards. Where replacement of obsolete plant and equipment can be justified on a "reasonable return on investment" basis, such programs have a place in the long-range plans of any company. The capital appropriations for such replacements, however, are often far down on the list of priorities for action. Consider such a contrast as is provided by the steel industry of Japan, where 90 percent of existing facilities have been built since the late 1950's, using the best technological developments in the world. They have been encouraged to build such an industry by incentives to develop a strong export market as well as by a growing domestic economy. Not the least of their success has come from the attraction and utilization of very competent engineering talent to apply and further develop their technology. An accompaniment of this "success," of course, has been a

severe and growing pollution problem, which we must avoid both by limiting polluting aspects of development and by incorporating the costs of environmental protection and clean-up into the costs of production.

Chapter V

GOVERNMENTAL INCENTIVES AND CONTROLS

The overriding materials problem that calls for increased attention to appropriate legislative and other governmental incentives and controls is the problem of assuring a flow of raw materials into the national economy sufficient to maintain its strength during a period of continued growth of population and demand for such materials. Simultaneously, such incentives and controls must take into account the need to conserve materials, enhance the durability of goods and quality of the capital stock, and safeguard the environment -- in other words, to move in the direction of stabilizing the man-resources system.

SOME ISSUES

The issues are many. Among the more important are these four:

1. How can we prevent or abate the wasteful or harmful use or loss of irreplaceable materials by the private sector, brought about in advanced industrial societies because repair requires hand labor, which costs more and more relative to the original cost of manufactured products, by planned product deterioration and obsolescence, by conspicuous consumption, and by disperal of materials?

2. <u>How can we prevent or abate the wasteful or harmful use or loss of irreplaceable materials as a consequence of governmental actions or inactions</u> whose effect is to stimulate production and consumption, or waste, of non-renewable resources, and to externalize social and environmental costs?
3. <u>How can materials information be used more effectively in national policy and strategy</u>, in incorporating changing public priorities and values into resource-oriented decisions, in resolving conflicts of interest among states and regions that threaten a more unified national materials policy, and in illuminating the hazards of uncritical faith in growth, in unspecified technology, in vague concepts of human ingenuity, in the "demographic transition," or in any combination of these? Where will the necessary leadership come from?
4. <u>How can flexibility of response to challenge be built into the decision structure</u>?

TRENDS

It is evident from all criteria that demand for materials will continue to grow. In view both of environmental problems and of the certainty that supply of most mineral materials cannot <u>indefinitely</u> keep pace with ever-increasing

demand, we see little alternative, in a well-managed society, to increase regulation on a national scale of the allocation and use of mineral resources. On the other hand, a wholesale and abrupt revision of existing policies and stragegies would probably be unworkable, even if we knew in detail what changes to make, because a perceived crisis of the required intensity does not exist. It seems more likely that we shall find our way to the lessening of future crises, if we do, by incremental changes in direction.

Many and large changes in social values and political priorities are taking place in the nation, accompanied by a pervasive distrust of established authority at virtually all levels. A new economic protectionism is growing, expressed not only at the national level but within states and even local units of government. These trends, making more difficult the imposition of regulations or controls that may be needed, must be dealt with in considering materials policy. The desire to protect jobs and income at home is raising barriers to imports; the desire to preserve local economic growth is causing some producing states to reconsider their commitment to supply mineral products to the rest of the nation; the desire to protect local environments is lowering the potential for mineral production in many parts of the country and will continue to do so without price increases to cover costs of environmental protection and restoration.

The American life style, insofar as it depends upon materials, is changing and will continue to change in the near

future as the nation pays the deferred social costs of past consumption and inequities in distribution and begins to calculate the costs of depletion, replacement of non-renewable resources, and environmental restoration and protection.

ASSUMPTIONS AND JUDGMENTS

Recognizing that we are dealing with a subject about which views are diverse and strong, and evidence is often not clear-cut, we preface this discussion with a brief statement of assumptions and judgments.

Governmental incentives and controls should be straightforward, equitable, and flexible. Our consideration of various regulatory systems leads to the judgment that good and different incentive mechanisms can meet different needs at different times. However, for many materials situations, price control (not necessarily downward) may well be more effective than other alternatives, such as selective taxation or subsidy. In addition, as much or more attention should be paid to controlling materials-consuming growth as to increasing supply. Resource data should be evaluated on an energy and materials balance basis, rather than just on an economic basis. The grant-in-aid, direct or indirect, is a defective control mechanism, for it creates a special-interest group, promotes inefficient allocation of resources, and decreases flexibility of response to changing needs. Members of mater-

ials interest groups, be they producers, processors, purveyors, or purchasers, should be treated equally within groups and equitably among groups. Technologic, economic, and social efficiency of materials use calls for study of how individual and collective freedom to waste materials can be most effectively and democratically limited.

DISCUSSION

Materials positions tend to be volatile. The glut of today may be the dearth of tomorrow. In such a situation, regulation of some kind is needed to dampen fluctuations and hold them within manageable limits. Government actions that are or could be applied to mineral-resource production and consumption are listed in the table that follows this discussion. This tabulation is presented only as a convenient way of visualizing alternatives, in full recognition that the net effect of a government action must be measured in terms of national objectives, which remain unidentified in this table. Import restrictions on a specific material, for example, can work _in favor_ of national security and regional economic health, but at the same time _against_ national economic efficiency and environmental quality. Time was not available to analyze this matrix of cause and effect, of conflicting aims and tradeoffs, but it should be explored.

The need to increase materials supplies and reserves and to maintain access to supplies not under U. S. political control is discussed in Chapters 1, 4, and 6. Here, therefore, we emphasize the need for restraint of demand, growing out of the conviction

(a) that the demand side of the demand-supply equation has received far too little critical analysis, as implied by pages 6-7 of the April 1972 Interim Report of the National Commission on Materials Policy, a two-page list of "Materials Issues and Problems" that nowhere alludes to review, analysis, or restraint of demand;

(b) that, for some materials, restraint of demand offers greater possibilities of approaching a supply-demand balance than encouragement of supply increase;

(c) that, in the long-term use of non-renewable resources, restraint of demand is the rational way to approach the inevitable substitutions required by physical depletion and economic exhaustion of some of those resources; and, finally,

(d) that the entire existing system for materials decision-making is so biased in favor of production and consumption that one can hardly overstress the need for temperance and foresight in monitoring and controlling wasteful and non-essential uses.

Possible government actions in regard to mineral-resource production and consumption:

Action	Impact on domestic production	Impact on domestic consumption
A. FINANCIAL		
(1) Production subsidy, direct	+ to -	
(2) Production subsidy, indirect	+	
(3) Depletion allowance	+	
(4) Tariff or duty on imports	+	
(5) Federal lease bonuses and royalties	- to 0	
(6) Government purchase and use practices	+ to -	
(7) Exploration loans (e.g., OME)	+	
(8) Government subsidy (including dedication of taxes) of mineral-using activities (highway, airport construction)		+
(9) Government stockpile accumulation (domestic materials)	+	
(10) Availability of government-identified resources	+	
(11) Price controls	-	+
(12) Consumer taxes		-
(13) Production (severance, effluent taxes)	-	
(14) Government stockpile reduction	-	
(15) Support of materials research and development	0 to +	+ to -
(16) Change from claim to lease system for minerals	- to +	
(17) Incentives for foreign production	0 to -	
(18) Depreciation	+	
(19) Expensing of exploration costs	+	

Action	Impact on domestic production	Impact on domestic consumption
B. PHYSICAL		
(1) Import restrictions	+	
(2) Federal land-leasing rate	+ to -	
(3) Payment for deferred production	-	
(4) Prohibition of production activities	-	
(5) Zoning and withdrawal of land	-	
(6) Prorationing	-	
(7) Operational regulations (waste-disposal, health, land-reclamation)	-	
(8) End-use controls		-
(9) Impurity limits (sulfur, mercury, e.g.)		-
(10) Regulations requiring building design to conserve materials		-
(11) Regulations allowing or requiring internalization of all external or social costs of production		-
(12) Regressive taxation of low-efficiency uses of scarce materials		-
(13) Export controls		+

RECOMMENDATIONS

1. An effective monitoring system for materials supply, deliverability, reserves, use, substitutability, environmental impact, demand, and the efficacy and costs of incentives and controls is needed. Definition and assessment of trends are essential if potential crises are to be foreseen and averted or dampened.
2. The materials implications of existing social policies and government programs should be critically evaluated in light of the need to control demand and prevent waste and environmental deterioration. This applies even to programs whose objectives are not materials-oriented. National strategic objectives such as full employment, regional economic development, and even environmental quality stimulate resource consumption; consequently, the social costs of such objectives include resource depletion, materials dispersion, and energy degradation.
3. National reserves of specific critical materials should be established, based on projected needs of the economy, estimated uncertainty of supply, and state of technology.

4. Government should not hesitate to enter materials markets, as either buyer or seller, in order to achieve essential regulatory objectives, as well as to maintain national reserves.
5. In special circumstances also, government should not hesitate to consider the nationalization of limited stocks of critical materials where necessary to prevent their wasteful use or loss of essential and conservable materials to future generations.
6. State and regional economic protectionism should be discouraged wherever it threatens to introduce irrationality into an effective national pattern of materials management.
7. We need to learn more about social perceptions and attitudes that involve materials, in order to be able to estimate and influence acceptability of incentives and controls.
8. We need to devise incentives to encourage development of the technical ability to use renewable resources in place of non-renewable ones and to use abundant materials in place of scarce ones.
9. To the extent practicable, government incentives and controls applied to shared resources and impacts should harmonize with those of our neighbors. Some materials

and environmental resources, such as those of the Great Lakes and the Gulf of Mexico, not to mention the world oceans, are international commons. In other instances, the development and use of domestic materials produce or can be expected to produce impacts on neighbor nations. Failure to agree on common policy for the management of such resources and the control of such environmental impacts threatens both the commons and the national image.

CONCLUSION

In conclusion, it is our opinion that there is a growing need for leadership at the highest national and international levels for more equitable and harmonious allocation of resources between present and future generations and between geographic areas, as well as elucidation at this same level of the dangers and opportunities to which society should respond. Difficult though this may be, we consider such an effort to be vital to an effective and moral materials policy.

Chapter VI

INTERNATIONAL IMPLICATIONS OF MATERIALS POLICY ISSUES

All signs point to a growing world need for materials. For most countries, there will be an increasing interdependence on sources of raw materials. The United States, as one of the world's major industrialized nations, will continue to need broad access to varied sources of supplies.

In 1950 the world produced about 200 million tons of steel, of which the United States produced 47 percent, whereas in 1971 the world produced about 640 million tons of steel, of which the United States produced only 19 percent. Because world material supplies generally move roughly in proportion to steel production, these figures, together with trade data, show:

1. A growing increase in world demand for raw materials;
2. A less dominant U.S. position in world production;
3. A growing international competition for acquisition of usable raw materials, especially with the United States.

Rising world concern with problems of the environment, moreover, suggests that developed countries in particular will become more concerned with efficient utilization of resources by methods of production less damaging to the environment.

On the international scene, some countries, Japan, for example, have developed apparently efficient and flexible com-

bined government-industry mechanisms that represent the interests of an entire industry abroad. At the same time, countries with centrally planned economies can also effectively represent abroad the interests of an entire industry segment. Governments of developing nations increasingly want greater control over development, sales, and exports of raw materials, as well as participation in or control of management. In addition, they are pressing for domestic processing of raw materials so as to ship semi-manufactured or refined products and thus derive the increased employment and income resulting from value added in industrial operations. Mechanisms must be found to cope fairly with such pressures at a national level, and to reduce the present conflicts between government and the mineral industries within the United States.

SOME ISSUES AND RECOMMENDATIONS

1. What should be the nature of the industry-government relationship within the United States in order to bring needed closer cooperation concerning materials problems? We suggest that a permanent Minerals Advisory Council be formed, composed of representatives from industry, government, and academia.
2. What laws or executive orders must be modified, and in what way, in order to permit the necessary close industry-government cooperation? We believe that the

effects of antitrust laws and conflict-of-interest regulations should be carefully reevaluated with a view to introducing modifications needed to protect valid national interests in the international materials field.

3. Is insurance currently provided by the United States for overseas investment adequate to meet foreseeable risks, to promote needed materials development, and to strengthen the proper interests of U. S. resource industries abroad? We recommend that the proposed International Investment Insurance Agency (I.I.I.A.) be studied and evaluated with a view to wider support.

4. Are special incentives needed to encourage development abroad of resources believed needed by the domestic economy and to what extent are they appropriate? We recommend that the Defense Production Act be extended and sufficient borrowing authority thereunder be made available to meet essential national needs, while concurrent study is made of the prospects and tradeoffs related to establishment of a more self-sufficient and conserving national minerals policy. Other mechanisms should also be explored, as discussed in Chapters 1, 3, 4, and 5.

5. How can the United States encourage the use of the facilities of the International Center for the Settlement of Industrial Disputes? We recommend that U. S. companies be informed by the federal government of the existence of this agency and encouraged to include ap-

propriate clauses in contracts and agreements involving foreign entities.

6. Should an interagency group make estimates of the relationship between population growth and demand for limited resources on a continuing and global basis? Should the United States Government encourage similar estimates by an international body in order to strengthen participation and mutual understanding? We recommend active support of both ideas.

7. In view of increasing United States imports of oil and gas, what are the policy implications over the next few years with respect to

   a. developing a common policy with other OECD countries on participation by producing countries, and

   b. the likelihood of convincing producing countries of the desirability of a stable, long-term market?

   What is the likelihood of importing liquified natural gas on a large scale?

8. What is the likelihood of international agreement on institutional arrangements affecting marine resources (the U.N. Law of the Sea Conference in 1973)?

9. What is the international responsibility of countries for pollution damage to other countries? What is the likely impact on foreign trade and investment of certain materials industries if higher levels of environmental protection are adopted in the United States? In other developed countries? Will environmental problems likely encourage

increased use of natural as opposed to synthetic products because they are more readily degradable by natural processes and thus less of a threat to the environment?

10. <u>What national policy measures can the developed countries take to encourage recycling</u> and thus bring about more efficient use of limited resources?

Chapter VII

MANPOWER AND FACILITIES

A national materials policy must inevitably include a "people" policy, and so we have set forth what we perceive to be manpower problems as they relate to education, industry, and the federal government. While solutions call for better communication among all these groups, the federal government appears to be the major source for needed funds and of comprehensive policy related to manpower (including womanpower).

We have limited the discussion to mineral science and technology, exploration, mining, beneficiation, and extractive metallurgy (as shown in Fig. 1, page 8, of the NAS Report on Minerals Science and Technology, Washington, D. C., 1969).* Furthermore, we see the need for training as including not only technical but also semi-skilled and non-skilled people.

Our first, and recurring, observation is that data on manpower supply and demand are incomplete, inaccurate, misleading, often misinterpreted, and are therefore much in need of improvement. Moveover, time has not been sufficient to undertake the study needed to correct this. Scientific manpower problems in general have been treated in more studious and detailed reports of the NAS and the Carnegie Commission; we

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* <u>op.cit</u>., p.39

confine ourselves here to some pooled judgments about manpower and facilities needs in the mineral industries.

ASPECTS AND PROBLEMS OF EDUCATION

1. Suitably trained people in appropriate numbers must be supplied to relevant industry and other employers. In the face of low or declining undergraduate enrollments in mineral curricula this is becoming increasingly difficult, and the lead-time for such training may be anywhere from two to ten years.
2. Better communications must be established between industry and educational institutions and with the students as to needs for training. In general, it seems that students make career decisions based on existing demands, which, when the lead-time has run out, may be wrong for the changed situation. It may also be that we are over-training some people. On this point there is now no agreement between industry and educators. All agree, however, that there is a growing place for continuing education, through short courses, seminars, extension classes, and other devices.
3. Materials science teaching and research need to be better integrated.
4. The uncertainty, the timing, and the short terms of grants and contracts are vexing problems for universities, while

rising costs continue to take their toll in deteriorating quality of programs, facilities, and equipment.

5. Too few students are enrolled in the many schools now offering minerals industry curricula. This results in under-utilization of facilities and exorbitant costs per student. Although more and more appropriately trained manpower is needed, this situation should be corrected before new programs are started.

6. The plight of the private school in the teaching of materials science and technology (as in other respects) is unresolved in any present plans.

7. The recent aid-to-higher-education bill is too restrictive. Talent exists in all classes and colors of people. A healthy and responsive minerals industry will need the best, irrespective of origin.

8. More qualified people from ethnic minorities, and women, must be attracted to the mineral industry professions. Better data are needed before the reasons can be clarified as to why this has not happened. Meanwhile, these groups should be encouraged to consider careers in relevant fields and assisted in training for them where interest and ability exist.

9. Students of foreign origin, on the other hand, are becoming relatively more numerous in mineral industry education. The pros and cons of this development have not been evaluated.

INDUSTRY-RELATED PROBLEMS AND OBSERVATIONS

1. Projections of the demand for trained people differ, and no one knows the real demand, the necessary level of education, or the specialties required. However, it is a nearly universal complaint that industry under-utilizes trained people.
2. It seems to be difficult or impossible to plan for "boom or bust" employment due to fluctuations in the economy. However, we should seek to do more than simply deplore the cycle as inevitable.
3. Although it is commonly stated that higher salaries would attract and hold people in the mineral industries, recent surveys show that salaries are, in fact, competitive.
4. The public image of the entire extractive industry needs refurbishing.
5. Policies in the mineral industries are ultra-conservative. The industry's contribution to formal education is minimal -- scarcely a token. It must be increased if the industry is to become self-rejuvenating. Although industry devotes considerable effort to on-the-job training, work-study programs, and in-house training, more of this, too, is needed to keep its scientific and technical personnel current with developing ideas and prepare them for new ventures.

6. A growing problem in the industry is unionization as opposed to professionalism of technical people.
7. More impelling and judicious incentives than legislated quotas are needed to get qualified people from all groups into the mineral industries.

GOVERNMENTAL IMPACTS

1. Federal funding of research and student training in the materials field should be increased and diversified. It has, in the recent past, been mostly provided by DoD, AEC, and NASA. Support of the material sciences laboratories previously provided by ARPA has been transferred to NSF. In the geological and mineral sciences fields, although there has been a long tradition of cordial collaboration, such funding as has been provided by the professional organizations most closely related to materials, the U. S. Geological Survey and the U. S. Bureau of Mines, is inadequate for current and anticipated future needs in the minerals profession. If Senate Bill S-635, now being discussed in the Congress, is enacted and appropriately funded, a major step forward should become possible.
2. The role of government in education for the mineral sciences should be limited to in-house training, cooperative programs, and support of formal education and training in both public and private established educational institutions with competitive standards. The federal government should not be in formal competition with private or state professional educational institutions.

SOME STEPS TOWARD SOLUTIONS, AND SOME CAUTIONARY REMARKS

1. It is too simple to say that money will cure most of the problems, but we believe that, if manpower requirements are to be met, very substantial supplemental funding will be needed for higher education in the mineral industries and related environmental management and that such funds should come from both industry and government.
2. Although several of the solutions to problems mentioned above involve government, we have not had the time to analyze potential sources of funding, including federal, or to formulate concrete policy recommendations. That should be done, however, and appropriate action taken.
3. The results of the Western Interstate Commission on Higher Education (WICHE) mutual aid pact, involving eight western U. S. institutions, should be watched carefully, although it is still too early, perhaps by several years, to evaluate them.
4. We agree that existing and potential centers of excellence should be strengthened before consideration is given to establishing additional institutions for education in the mineral industries.
5. We unanimously agree that a national mining school is not desirable.

ONLY ONE EARTH

THE CARE AND MAINTENANCE OF A SMALL PLANET BY *BARBARA WARD* AND *RENÉ DUBOS*

An Unofficial Report Commissioned by the Secretary-General of the United Nations Conference on the Human Environment, Prepared with the Assistance of a 152-Member Committee of Corresponding Consultants in 58 Countries

W · W · NORTON & COMPANY · INC · *NEW YORK*

PREFACE

THIS REPORT is the result of a unique experiment in international collaboration. A large committee of scientific and intellectual leaders from fifty-eight countries served as consultants in preparing the report, of whom more than seventy made detailed written contributions directly to the work of preparing it.

The names of Barbara Ward and René Dubos are listed quite properly as authors of the report. They are indeed responsible for the drafting and revision of the manuscript to which they both contributed at personal sacrifice, under remorseless time pressure, with unstinting assistance of a very small staff, and without compensation. They are responsible, too, for its general style. It would be quite impossible to describe adequately the spirit and energy that they invested in its enterprise.

But in this case the role of the "authors" is more accurately described as creative managers of a cooperative process—one which engaged many of the world's leading authorities as consultants in the multiple branches of environmental affairs. Their names appear elsewhere.

As Secretary-General of the United Nations Conference on the Human Environment, I commissioned Dr. Dubos in May 1971 to serve as chairman of a distinguished group of experts who would serve as advisers in preparing the report. The aim was to reach out for the best advice available from the world's intellectual leaders in providing a conceptual framework for participants in the United Nations Conference and the general public as well. Members of the group of consultants were asked to read a preliminary manuscript and offer their criticisms and contributions. The letter appointing Dr. Dubos stated that the greatest value of the report would "derive precisely from the fact that it will represent the

knowledge and opinion of the world's leading experts and thinkers about the relationships between man and his natural habitat at a time when human activity is having profound effects upon the environment."

This report has been considered an integral part of preparations for the United Nations Conference. At the same time it is the work of individuals, serving in their personal capacities without restraints imposed upon officials of governments and international agencies. Thus the report is not an official United Nations document but a report *to* the United Nations Conference Secretariat from an independent expert group. The only restraint on those who prepared the report was a request that they not prejudge the work of governments at the United Nations Conference by proposing specific international agreements or actions—its main purpose being to provide background information relevant to official policy decisions.

Many were skeptical of the workability of the procedure adopted for preparation of this report. Yet with less than thirty days to study the preliminary draft, prepare their comments, and return them to New York, more than seventy such contributions were received in time to be considered in the course of revising the manuscript. Almost without exception, the comments from the group of experts were substantive, specific, and constructive. Many were lengthy and detailed.

As the authors stress in the introduction, there are contrasting views about the social application of important categories of available technology even where the scientific facts are not in serious dispute. In other cases viewpoints expressed by consultants in effect canceled each other out by recommending that the drafters give countervailing weights to various factors and considerations. Some found the tone too alarmist; others found it too optimistic. All this is very valuable because it is just as important for the decision-maker to know that experts disagree as it is to find that a consensus exists. It also means, inevitably, that everyone cannot be satisfied at the same time; perhaps none of the contributors will be *wholly* pleased with the final text, certainly not the few whose useful comments unfortunately arrived too late to be taken into account. But I know that the managers of this difficult creative process have made every effort, under the most pressing circumstances, to find a balance among frequently contrasting views.

More specifically, the consultants provided a great deal of invaluable guidance in the formulation of scientific issues in suggesting rearrange-

ment of material and in verifying or correcting factual points.

The United Nations Conference Secretariat is not responsible for the content of this report, nor is it called upon to endorse it in whole or in part. But the Secretariat does welcome enthusiastically the success of the collaborative process by which it was produced and expresses the deepest appreciation to members of the consulting group and to all those many people who, in one way or another, aided in this remarkable process.

Finally, I must offer profound thanks to the Albert Schweitzer Chair at Columbia University, the World Bank, and the Ford Foundation for fully funding the cost of this report. The International Institute for Environmental Affairs provided highly effective overall management of a complex process with no precedents to provide guidance.

Maurice F. Strong
Secretary-General
United Nations Conference on the Human Environment

INTRODUCTION

THIS INTRODUCTION is distilled from about four hundred pages of correspondence, originating from forty different countries. It is inspired by the letters we received in reply to our request both for criticisms of the preliminary draft of *Only One Earth* and for suggestions as to what should be emphasized in the final text. From the tone of the letters, many of which greatly exceed ten pages in length, it is clear that most of our consultants are intensely worried about the state of our planet, but that very few if any of them regard the situation as hopeless. The vibrant concern of so many thoughtful and learned persons, from many different parts of the world and different fields of human endeavor, is enough reason for sober optimism.

We are, of course, immensely grateful to our consultants for calling to our attention factual errors, omissions, and misplaced emphases in the preliminary draft. But the most rewarding and illuminating aspect of their replies was the diversity and richness of the conceptual points of view they expressed concerning the problems to be discussed by the U.N. Conference on the Human Environment. The very ambiguity of the phrase "human environment" clearly provided the consultants with the opportunity to formulate their social and scientific philosophies and to explore the consequences of their attitudes in operational terms.

The spectrum of views among our consultants was much wider than we expected; but far from resulting in confusion, the diversity of their attitudes toward the environment turned out to be the expression of the richness of man's nature—and it is this richness which accounts for the diversity of civilizations. Free human beings differ not only with regard to the characteristics of the environmental settings which they find most desirable, but also with regard to life-styles, aspirations, and last but not

least their views of man's place in nature. Experts as well as laymen usually find it easy to agree on purely objective scientific issues. But the U.N. Conference is not focused on abstract problems of theoretical ecology. It is primarily concerned with the characteristics of the environment which affect the quality of human life—a very subjective and ill-defined concept.

In his reply, one of the consultants from Africa urges us to spell *Man* with a capital *M*, instead of writing about man or men. In our opinion, this is not trivial stylistic advice. It symbolizes rather a conceptual problem which inevitably confronts environmentalists in all their practical discussions and decisions. Are men simply higher apes, and as such of no greater significance than other components of the natural ecosystems? Or does *Man* occupy a special place in nature?

Those of our consultants whose primary interest is theoretical ecology naturally urge that emphasis be placed on the earth ecosystem per se, man being considered chiefly as a disturbing element in it. And there is no doubt indeed that most of our present environmental difficulties originate from man's ecological misbehavior. Increasingly we consider ourselves not as lodgers on the earth, but as its landlords; we identify progress with the conquest of the external world even if this means destruction of those parts of nature which we assume—often erroneously—to be irrelevant to our welfare. But while it is possible that *Homo sapiens* could survive as a biological species after impoverishing and spoiling nature, could *Man* long retain his humanness in a desecrated environment?

The statesmen who planned the U.N. Conference on the Human Environment certainly had in mind the physical and spiritual qualities of man's relation to the earth, at least as much as the ecological health of our planet. They were naturally preoccupied with the shortages of food and amenities, the depletion of natural resources, the accumulation of environmental pollutants, the increase in the world population, and also the threat to certain natural values which transcend bodily needs. They realized in addition that all these problems have acquired an element of extreme urgency from the fact that mankind has now spread over the whole surface of the globe. By the year 1985, according to recent estimates, all land surfaces will have been occupied and utilized by man except for those areas which are so cold or at such high altitudes that they are incompatible with continued human habitation or exploitation.

The U.N. Conference on the Human Environment comes therefore at a very critical time. Now that mankind is in the process of completing the colonization of the planet, learning to manage it intelligently is an urgent imperative. Man must accept responsibility for the stewardship of the earth. The world *stewardship* implies, of course, management for the sake of someone else. Depending upon their scientific, social, philosophical, and religious attitudes, environmentalists have somewhat different views as to the nature of the party for whom they should act as stewards. But in practice the charge of the U.N. to the Conference was clearly to define what should be done to maintain the earth as a place suitable for human life not only now, but also for future generations.

The depletion of natural resources is, of course, one of the chief reasons of uncertainty concerning the continued ability of the earth to support future human civilizations. Concern about future supplies of natural resources is so widespread and so deep that one of our consultants, from a highly industrialized affluent European country, went as far as suggesting that mankind must begin very soon to retreat from industrialization and to focus efforts on the development of more efficient agricultural techniques! Thoughts of retreat from industrialization, however, are not congenial to the consultants who belong to parts of the world which are only now beginning to industrialize in order to lift themselves from poverty. They are aware of the dangers inherent in industrialization, but they see it as the only road to higher living standards. In fact, almost any method of industrial development which gives hope of more abundant food production, less unemployment, better public health, and a decent level of amenities must have in their judgment precedence over considerations of future environmental damage.

Since industrial growth depends upon the availability of large amounts of electric power and of certain chemical products, it is not surprising that policy-makers and planners from countries which are seeking economic development are not likely to be sidetracked, in the words of an Asian statesman "by dreams of landscapes innocent of chimney stacks." There is indeed a widespread acceptance of the fact that environmental pollution is an inescapable by-product of industrial development. Experience shows furthermore that societies have become preoccupied with long-range ecological consequences only after industrialization had provided them with a high level of economic affluence. "Sufficient unto the day is the evil thereof" has been the law which has

so far tacitly governed much of man's behavior toward the environment. If history repeats itself in this regard, it is likely that in most places and for many years, environmental quality will be subordinated to developmental goals.

Economic affluence, however, is only one of the factors affecting civic consciousness in its attitude toward the environment. The difficulty of settling by scientific expertise the comparative importance of technological and environmental considerations in industrial development is well illustrated by the profound differences of views among our consultants regarding nuclear power.

On the very same day we received forceful statements on nuclear power from two Nobel laureates, both equally illustrious for the magnitude of their achievements in the natural sciences and for the importance of their social contributions as leaders of national agencies and as advisers to international bodies. Both, furthermore, are from highly industrialized English-speaking countries. According to one of them, the text of *Only One Earth* does not do full justice to the potentialities of nuclear power and greatly exaggerates its threats to natural ecosystems and to human health; in contrast, the other Nobel laureate affirms that nuclear power should not be developed at all, because, in his words, it is "utterly inappropriate in the biosphere." Many other consultants have expressed equally strong views on both sides of this controversy.

As could be expected, similar contrasts of opinion repeatedly occur among the consultants with regard to pesticides. One of them informs us that he probably would be dead if DDT had not been available at the time he was working in Guyana; in the same vein, many others repeatedly assert that millions of people will soon die of infectious disease or of malnutrition if attempts are made to limit drastically the use of pesticides in public health practice and in agriculture. There are many other experts, on the other hand, who are convinced that natural ecosystems are even now profoundly disturbed by pesticides and who predict that the earth will progressively become unsuitable to human life if present trends of pesticide use are continued.

A highly important but confusing anthology could thus be compiled from the spectrum of views sent by our consultants regarding the effects of technological intervention into the human environment:

- Some are more impressed by the stability and resilience of ecosystems than by their fragility.

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· Some would emphasize human settlements rather than natural ecosystems and nature conservation.

· Some would give priority to water pollution, others to the state of the atmosphere, still others to the problems of land management.

· Some believe that environmental pollution and the depletion of natural resources can best be controlled by individual behavior, others by strict controls over industry, and still others by a complete transformation of the political structure or of life-styles.

· Some believe that the most destructive forms of ecological damage flow from types of high-energy, high-profit technology whose advantages are grossly overstated in terms of genuine utility, others see energy as *the* key to the basic economic achievement of producing more goods for fewer inputs and thus incomparably widening the citizen's wealth and choice.

· Some see the solution of environmental problems in more scientific knowledge and better technological fixes, others in socio-economic morality, and still others in the cultivation of spiritual values.

· Some object to the phrase "developed countries" because they believe that no part of the world is yet adequately developed; others in contrast believe that industrial development has gone too far in the affluent countries and must be reduced within limits determined by man's ability to stabilize the economy of the earth's resources. As mentioned earlier, certain consultants from highly industrialized countries go as far as advocating a return to an economy based on agriculture and believe the developing countries would be unwise to regard technology as the way to the future.

There was general agreement among the experts that environmental problems are becoming increasingly world-wide and therefore demand a global approach. But two consultants from two different Asian countries suggest that little progress will be made, either in economic development or in environmental improvement, until each particular country has learned to manage its own ecosystem. As they point out, there are many different worlds within our theoretical One World, each differing from the other not only in physical characteristics and economic structure, but even more importantly perhaps in cultural traditions and in aspirations.

Some of the consultants feel that the general tone of *Only One Earth* is far too pessimistic and they see no justification in reporting on the

present state of the world as if it were a "fear story." One of them, indeed, sees in the style all the defects he violently objects to in *Silent Spring*—"emotional and non-factual." Other consultants, in contrast, would like the book to issue a more forceful warning—a clarion call—that present environmental trends cannot continue much longer because mankind is on a course of self-destruction. One consultant specifically urges the authors of *Only One Earth* not to let the editorial staff reduce the book to a mere recital of facts because salvation will ultimately depend on an emotional awakening.

The list of conflicting views and recommendations received from our consultants could be extended to many pages. It constitutes a spectrum of expert opinion on environmental improvements which ranges all the way from the advocacy of technological fixes to a plea for new religious attitudes. At first sight, this discrepancy of opinions appears to constitute evidence for the commonly held view that experts do not agree on facts and therefore are of little help in formulating programs of action. But in reality experts rarely disagree on the validity of the facts themselves; they differ only with regard to the interpretation and use of these facts.

No one doubts, for example, that ionizing radiations increase mutation rates, that most mutations are deleterious, and that some damage to human life and to ecological systems is therefore likely to result from the increase in radiation level—small as it may be—that will inevitably be caused by the operation of large numbers of nuclear power plants. But while all scientists agree on these facts, individually they differ as to the levels of radiation they consider tolerable, because this involves social considerations based on value judgments. For example, the biological hazards resulting from the industrial use of nuclear power must be balanced against the advantages to be derived from the economic development made possible by this power. Needless to say, similar arguments could be developed for most other technological innovations.

The problem of value judgment is further complicated by the fact that, in addition to the initial effects of technological interventions, there commonly occur indirect and delayed consequences which are difficult to predict and to evaluate. DDT causes little if any direct and immediate damage to man when used under reasonably controlled conditions. Its toxicity for the large ecosystems of nature, and eventually for man himself, becomes evident only after prolonged periods of usage which result in its progressive accumulation in the food chains. Technological

interventions must therefore be judged not only from the point of view of their effects in the here and now, but also with regard to the possibility that they will affect man, or his environment, or both at some later date. The U.N. Conference on the Human Environment could serve the very useful purpose of highlighting the need to focus social and scientific attention on the indirect and often unpredictable delayed responses made by complex ecosystems to social and technological innovations.

Since policies concerning the human environment require both social judgment and specialized scientific knowledge, perceptive and informed laymen can often contribute as much as technical experts to their formulation. In certain cases, indeed, laymen may be wiser judges than experts because their overall view of the complexity of human and environmental problems is not distorted by the parochialism which commonly results from technical specialization.

The diversity of views held by experts, even within a given social system and a given nation, points to the nature of the difficulties that will certainly face the delegates at the U.N. Conference on the Human Environment. In most cases, the difficulties will originate not from uncertainties about scientific facts, but from differences in attitudes toward social values.

The establishment of a desirable human environment implies more than the maintenance of ecological equilibrium, the economical management of natural resources, and the control of the forces that threaten biological and mental health. Ideally it requires also that social groups and individuals be provided with the opportunity to develop ways of life and surroundings of their own choice. Man not only survives and functions in his environment, he shapes it and he is shaped by it. As a result of this constant feedback between man and environment, both acquire distinctive characteristics which develop within the laws of nature, yet transcend the blind determinism of natural phenomena. The exciting richness of the human environment results not only from the immense diversity of genetic constitution and of natural phenomena but also and perhaps even more from the endless interplay between natural forces and human will.

Ambassador Adlai Stevenson clearly had in mind the overpowering influence of man's role in determining the quality of the environment and therefore of human life when, in his last speech before the Economic and Social Council in Geneva on July 9, 1965, he referred to the earth as a

little spaceship on which we travel together, "dependent on its vulnerable supplies of air and soil." We are indeed travelers bound to the earth's crust, drawing life from the air and water of its thin and fragile envelope, using and reusing its very limited supply of natural resources. Now that all habitable parts of the globe are occupied, the careful husbandry of the earth is a *sine qua non* for the survival of the human species, and for the creation of decent ways of life for all the people of the world. The fundamental task of the U.N. Conference on the Human Environment is to formulate the problems inherent in the limitations of the spaceship earth and to devise patterns of collective behavior compatible with the continued flowering of civilizations.

It is deliberately that, in the last paragraph, we have used the word *civilizations* in the plural. Just as individual human beings differ in their life and aspirations, so do social groups. This is obvious from the wide range of views—often so far apart as to seem incompatible—expressed by the consultants to the Report on the World Environment. But far from being a reason to despair, this divergence of views is in fact the expression of one of the most appealing aspects of the human species—its diversity. There are possibilities within the human environment for many different kinds of surroundings and ways of life.

While collaborating with a large international group in the preparation of *Only One Earth*, one of us (René Dubos) was simultaneously working on another book in which he emphasizes the importance of developing the distinctive genius of each place, each social group, and each person—in other words of cultivating individuality. These two endeavors are not incompatible; in fact, they correspond to two complementary attitudes. The emotional attachment to our prized diversity need not interfere with our attempts to develop the global state of mind which will generate a rational loyalty to the planet as a whole. As we enter the global phase of human evolution it becomes obvious that each man has two countries, his own and the planet Earth.

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THE FOLLOWING INDIVIDUALS agreed to serve as consultants and were invited to offer their criticisms and comments on an early draft of *Only One Earth.* The appearance of their names here, in grateful appreciation of their constructive help, does not constitute an endorsement of the book.

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CERN	European Center for Nuclear Research
CIAP	Inter-American Committee of the Alliance for Progress
ICSU	International Council of Scientific Unions
ISSC	International Social Sciences Council
IUCN	International Union for the Conservation of Nature
OECD	Organization for Economic Cooperation and Development
SCOPE	Scientific Committee on Problems of the Environment
SID	Society for International Development
UNCTAD	United Nations Conference on Trade and Development
UNESCO	United Nations Educational, Scientific and Cultural Organization

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Part One: The Planet's Unity

1 THE WORLD WE INHERIT

Man Makes Himself

MAN INHABITS TWO WORLDS. One is the natural world of plants and animals, of soils and airs and waters which preceded him by billions of years and of which he is a part. The other is the world of social institutions and artifacts he builds for himself, using his tools and engines, his science and his dreams to fashion an environment obedient to human purpose and direction.

The search for a better-managed human society is as old as man himself. It is rooted in the nature of human experience. Men believe they can be happy. They experience comfort, security, joyful participation, mental vigor, intellectual discovery, poetic insights, peace of soul, bodily rest. They seek to embody them in their human environment.

But the actual life of most of mankind has been cramped with backbreaking labor, exposed to deadly or debilitating disease, prey to wars and famines, haunted by the loss of children, filled with fear and the ignorance that breeds more fear. At the end, for everyone, stands dreaded, unknown death. To long for joy, support, and comfort, to react violently against fear and anguish is quite simply the human condition.

To some extent, these reactions can be found in other animals. Birds weaving nests, beavers building dams, animals hunting in packs are altering, "improving," and safeguarding their lives and their environments in a purposeful way. Man shares with his animal forebears many of the responses required for dealing successfully with a natural world that is at once beneficial and destructive. The original brain was an efficient receiver of sensation and director of appropriate emotional and sensory responses in the rest of the body—running from fire, cowering

from attacking beasts, embracing and love-making.

It is with the final stage in the brain's development that man, as man, begins to draw away from his ancestors. At some point, probably about a hundred thousand years ago, the forebrain became enormously larger and more complex. The skull of modern man is three times larger than the so-called Australopithecine hominid who is generally thought to be man's immediate predecessor. This change in size and structure of man's brain increases his ability both to receive sensations and to engage in abstraction, reflection, forethought, and the rational choice of goals. To serve abstract thought alone, we are told, the brain contains ten thousand times more components than the present generation of most complex computers. And the computer is yet to be invented that also smells, tastes, sees, and touches, thus adding to its capacity for abstract thinking all the emotional richness and complexity of a total human response.

This extraordinary development of man's brain lessens his dependence on animal instinct but is at the root of his creativity and his destructiveness. He can modify, more drastically than any bird or beaver, the conditions he finds unsuitable. And, having found his first experiment unsuccessful, he has far more immediate freedom to cast about and try something new. But he can also carry his experiments to disastrous points of no return from which instinctive reactions might have held him back.

This freedom has its counterpart. Some form of order must be imposed on such a range of possibility and risk. No social unit, even one as small as the family, can live on permanent change, innovation, and experiment. The instinctive response had to be supplemented by elements of a man-made social and physical design—first for self-preservation and then for all the extra dimensions of meaning—beauty, safety, and utility—which man could now conceive and therefore, in varying degrees, realize. From the start of his existence, man has innovated—in social forms, in technical improvements. His condition is to live aspiringly and uncertainly where the biosphere of living things and the technosphere of his inventions interact.

But today, as we enter the last decades of the twentieth century, there is a growing sense that something fundamental and possibly irrevocable is happening to man's relations with both his worlds. In the last two hundred years, and with staggering acceleration in the last twenty-five, the power, extent, and depth of man's interventions in the natural order

seem to presage a revolutionary new epoch in human history, perhaps the most revolutionary the mind can conceive. Men seem, on a planetary scale, to be substituting the controlled for the uncontrolled, the fabricated for the unworked, the planned for the random. And they are doing so with a speed and depth of intervention unknown in any previous age of human history.

The Beginnings of Innovation

Scale and speed are the keys to this revolution. If we look back over the pattern of man's millennial history, we can detect from man's earliest beginnings an underlying acceleration in both the variety of his interventions and the pace at which they succeed each other. This is not an order of "progress" in the optimistic sense of the eighteenth and nineteenth centuries. Good and bad are distributed all along the way. Some of the most fruitful inventions long precede other less fortunate ones. But it *is* a progression in the whole scale of man's ability to change his environment for both good and ill.

His first invention may be his greatest. It is language itself, the ability to communicate with other human beings through the symbols of speech, through words which are sounds to which agreed meanings have been attached. They made possible the organized activities of groups and clans. They underlay common strategies for the chase and the snare. They were at the beginnings of incantation and ritual, of poetry and the telling of tales. For tens of thousands of years, language has been man's most useful tool.

At some more recent date, a new and formidable intervention begins —the use of nonhuman energy to enhance human activity. In very early times, man learned to use animals to help him perform his work. But with the use of fire he begins his experiments with the earth's vast sources of nonanimal energy.

He is the first creature not to flee from fire. Perhaps he first used it in the hunt to frighten animals into the open. Perhaps one day, in hunger, he tasted a burnt animal that had not fled in time. Cooking began round the campfires, and the fire which had been tamed from raging energy in the dark forests and dry grasses would become in time the symbol of the hearth and the center of household use and comfort.

Fire, too, played its part in early man's greatest technical innovation

—the invention of settled agriculture. To this day in many subsistence economies, the basic farming technique is "slash and burn." The ash from burning trees enhances the soil. When fertility is used up and crops begin to decline, the clan moves to another part of the forest; trees grow again and their leaves eventually form new humus in the resting soil. This was one of the techniques by which some ten thousand years ago, in various parts of the planet, men learned to imitate nature's cycles of growth and thus began to free themselves from their millennial dependence upon hunting and food gathering.

It was, in fact, a period of incomparable inventiveness. Tools which, in the shape of sticks for shoving and picking or of rocks for weapons, man derives from his animal forebears were now refined by chipping or fashioning into the knives and axes and hoes of the Stone Age. Houses were built. Cloth and containers came from the newly invented loom and the potter's wheel. Brewing began. Cooking grew more varied and venturesome; the hearth warmed the house in colder climates.

Fire took men, too, beyond purely agricultural and domestic uses by making possible the metal ages. Once again, the chance sight of a surface metal melting in a charcoal fire may have first pointed the way to malleable metal for human use. Man could cease chipping and grinding stone and move to the smelting of metals. The Bronze Age and then the Iron Age followed the Stone Age. The relative durability of the new materials multiplied their uses. Every kind of implement became more sophisticated and versatile. So did decoration and embellishment. The instruments of the chase acquired new effectiveness. So did the weapons of war, the iron sword cleaving the bronze shield. And here, at a very early stage in man's use of nonhuman energy in developing technology, we encounter a strange and archetypal warning.

Fire helped to clear the forests and fertilize the fields. Fire smelted the metals. Fire warmed the hearths. Its use, helping to provide a surplus above mere subsistence, prepared the ground for the first large-scale experiments in organized civilization—in the Middle East, in North India, in China. Yet in one of the earliest Western mythologies fire is not a beneficent gift. It is stolen from the gods and Prometheus, the thief, is chained to the bare rock with a vulture at his vitals to avenge the blasphemous act. With this new power and ability to shape his environment, man is seen in Greek mythology to be playing a godlike part, creator, innovator, remaker of his world and of himself. This is his

dignity and freedom. But it is potentially the way to overweening pride and to an arrogance readily spilling over into the risk of destruction.

The Early Civilizations

The scale and pace of man's interventions increased further with each development and elaboration of civilized life. Early civilizations were based with few exceptions on river valleys whose waters were managed so as to bring reliable water supplies to the farms (still a major preoccupation in river-valley management). These vast river systems—on the Nile, the Euphrates, the Indus, and the Yellow River—required complicated administration and engineering to ensure their successful working. Bureaucracies grew up, vocations became more differentiated, a written language was needed since face-to-face consultation could no longer take place over such wide domains (many of the earliest written documents are inventories of palace and temple stores). Money was developed to take trade beyond the stage of village barter. Commerce opened the land routes and sea routes between Asia and the Middle East. Cities grew up round court and temple. Bureaucrats, traders, artisans moved to the centers of power. Above all, the management of waters required reliable measurements of land and flood and exact knowledge of times and seasons. Mathematics and astronomy were born among the Chaldeans and the Egyptians and later gave birth to the Greek vision of universal law which would embrace ultimate reality.

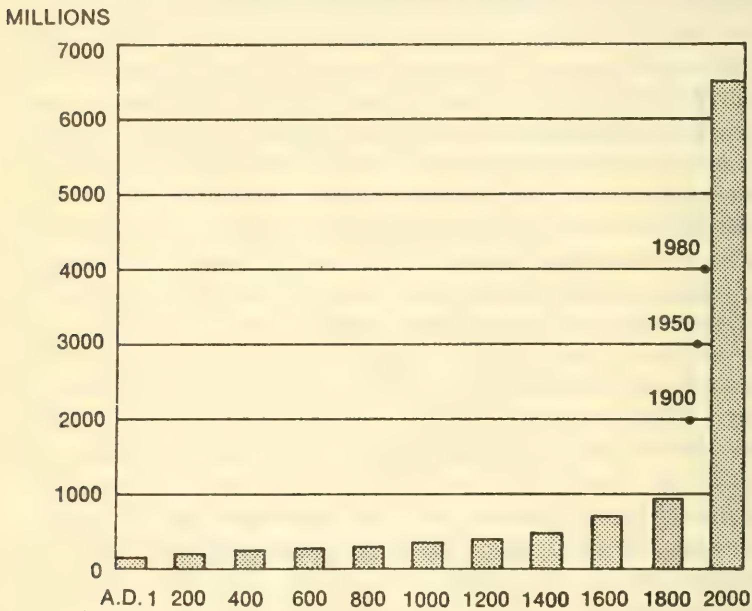
By the time the Han dynasty had come to power in China, and Rome had begun to assert its imperial control in the Mediterranean some 2100 years ago, civilized societies commanded most of the instruments of organization and technology that were to last man through another thousand years. They had alphabets and mathematical measures. They could use fire and water and winds and tides to supplement animal energy. They had learned to use a whole range of metals. They had elaborated on all the domestic and agricultural arts of neolithic man. They had cities and bureaucracies. They had coins and trade. This was the technological heritage upon which human society was to be very largely based for more than another millennium. Napoleon's land armies went no faster than Hannibal's. Charcoal still smelted iron ore until the eighteenth century. Water wheels powered the first factories. The Arabs knew as much mathematics as Galileo.

But in the seventeenth century the tempo begins once again to quicken. For a couple of hundred years, every index of growth—population, energy, use of food supplies, minerals consumed, people leaving the countryside and clustering in the cities—begins to mount. Many of the estimates are still guesses, but for population trends, use of energy, and increase in urbanization, they are probably not too far off the mark.

The Hinge of History

Then, in the twentieth century, as the accompanying charts illustrate, every index takes off for the stratosphere. Energy use, the consumption of foodstuffs and raw materials, urbanization, above all, population—every one of them seems to spring off the end of the graphs. Here, clearly, we confront one of those increases and accelerations in which quantitive changes are so great that they constitute a qualitative change. The whole human way of life is, as it were, pulling at its anchors in nature and in

WORLD POPULATION A.D.1–2000



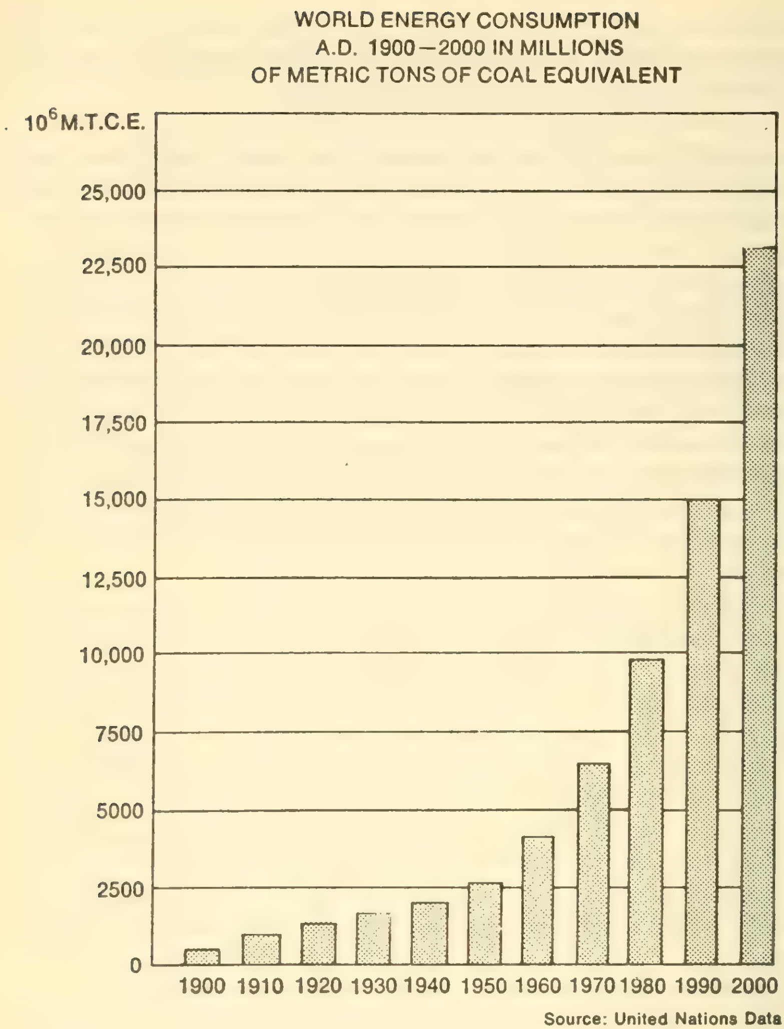
Source: United Nations Data

history and straining to set sail. Or should we rather say that it is gathering energy on its launching pad to take off, rocketlike, into regions as relatively uncharted as the surface of Mars?

At the core of the new situation is the interaction of increasing numbers of people, all using or seeking to make use of more energy and more materials, all tending to draw together in closer proximity in urban regions, all concentrating to a wholly new degree the by-products of their activities—their demands and consumption, their movements and noise, their wastes and effluents. The graphs give us some idea of the dimensions. World population edged up from the levels made possible by neolithic agriculture to perhaps 400 million by the fall of Rome. Over a thousand years later, about A.D. 1600 it reached the first billion. Thereafter the acceleration begins as a result of rising production in farms and factories as the Industrial Revolution gathered momentum and was followed by a steady fall in the death rate, particularly in infant mortality. The second billion arrives after only three hundred years, in 1900. The third took only fifty years. We are well on our way to the fourth in only thirty years—by 1980.

This rate of growth of population in the twentieth century has been accompanied by the settlement of virtually all the naturally inhabitable parts of the globe and an increase of more than a billion people in urban settlements of over 20,000 inhabitants, by a quadrupling of energy consumption, and a virtually uncountable increase in the consumption of depletable resources. Today it has been estimated that, on the average, a citizen in the world's wealthiest country—the United States—carries eleven tons of steel around with him in cars and household equipment and produces each year one ton of waste of all sorts. Even these brief indications are enough to show that the impact of man and his technology on his natural environment and resources is already radically different from anything yet experienced in human history.

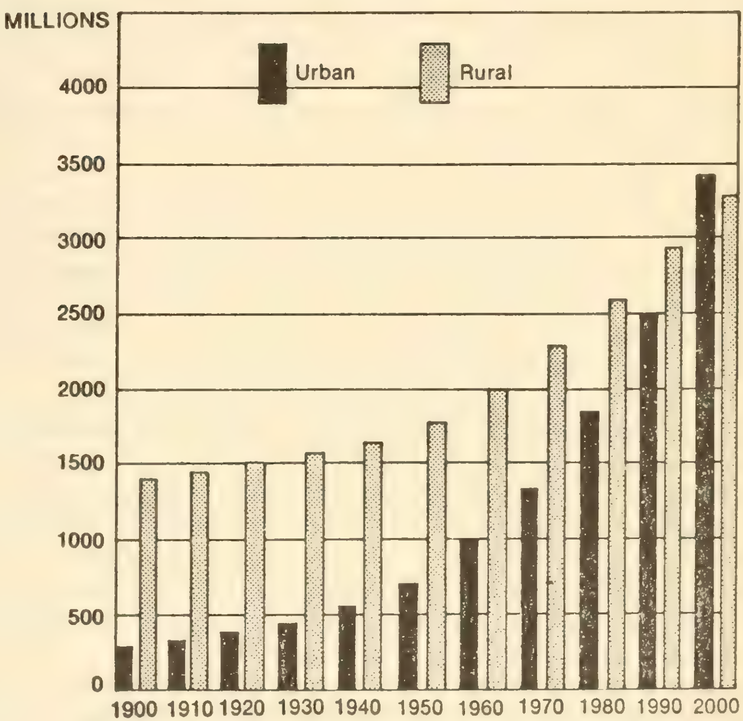
But this is only the beginning. If we extend our predictions only another thirty years, we have a likely world population of seven billion people. Urban inhabitants, at nearly three and a half billion, will outstrip rural people for the first time. Energy use will be thirty times greater than in 1900 and may have quadrupled since 1970. This, however, is simply an extrapolation from existing levels of use. But the two-thirds of the world's people who live in developing lands consume nearly eight times less energy per capita than do citizens in richer lands. Can we be sure


WORLD ENERGY CONSUMPTION
A.D. 1900—2000 IN MILLIONS
OF METRIC TONS OF COAL EQUIVALENT
10^6 M.T.C.E.
25,000
22,500
20,000
17,500
15,000
12,500
10,000
7500
5000
2500
0
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
Source: United Nations Data

that their demands may not undergo as startling an expansion? Is it conceivable that the next century may begin with seven billion people commanding, say at least half the energy use, food and metal consumption, and output of effluents reached today in the United States?

Before we dismiss the idea as a fantasy, it is well to reflect for a moment upon one fundamental factor in the energy-consumption equation. It is a fairly general characteristic of human nature that men seek to avoid backbreaking and monotonous work, that they like comfort, are fascinated by personal possessions, and enjoy having a good time. The

WORLD URBAN* AND RURAL POPULATION



Source: United Nations Data

*Urban refers to towns of more than 20,000 people

proof of this basic psychological bias can be seen in the behavior of any wealthy group ever since neolithic man began, through settled agriculture, to build up a surplus of goods above the level of tribal subsistence. That this bias can carry with it high costs in terms of boredom and triviality is not in doubt. But the point is that making three-quarters of the population affluent, as opposed to the traditional 1 per cent, will not make them less likely to want the things wealthy people normally want —very little menial work, a profusion of goods, and lots of chances for entertainment.

The reason why the modern age has seen, in a number of countries, an extension of wealth from a traditional elite to a much larger number of citizens is in part political. It stems from the emergence of equality as a general ideal—even if it is still fairly far from an achieved practice. But wider prosperity is due much more to the extensions of technology; above all, to the enormous increase in supplies of energy. Energy is at the root of the productivity, of the ability to make "more for less" that offers most citizens in a modernized society an inconceivably enlarged range of material choice.

One way of looking at this large expansion in personal opportunity has been suggested by Buckminster Fuller, who, thirty years ago, made an estimate of the amount of muscular energy needed to produce the then available supplies of power and suggested that each American had the equivalent of 153 slaves working for him. Today, the figure would probably be nearer 400 slaves and they do what slaves traditionally did— lighten domestic work, cook food, carry people about, rush in with fans and heaters, deliver clothes, finery, and ornaments which they have produced in the first place, play continous music (loudly or softly according to command), and remove garbage from the immediate vicinity. They are no longer men. They are powered machines. It is the space they take up, the power they use up, the wastes they give up that is at the core of some of the most pressing short-term problems in the human environment—the problems of pollution. But they are there because the mass of people want their "energy slaves" and find the experience of personal wealth an agreeable one.

We do not know whether those who now enjoy these standards will want ever higher ones—a move, say, from four hundred to a thousand energy slaves over the next twenty years—although the past behavior of rich groups does not suggest that appetite grows less with eating. We

cannot be certain whether societies which have modernized their economies by the route of public ownership and central planning will undergo quite the same pressures for increasing personal ease and consumption as do market economies—although socialist governments undoubtedly include a steadily rising standard of living among their national objectives. Similarly, we cannot be absolutely certain that the modernizing "South" of our planet will pursue so strenuously the goal of personal wealth—although in many societies the attitude of the elite hardly suggests a total rejection of the high-consumption model.

What *is* certain is that our sudden, vast accelerations—in numbers, in the use of energy and new materials, in urbanization, in consumptive ideals, in consequent pollution—have set technological man on a course which could alter dangerously and perhaps irreversibly, the natural systems of his planet upon which his biological survival depends. Today when only a third of humanity has entered the technological age, the pressures are already apparent. Rivers have caught fire and burned their bridges. Lakes and inland seas—the Baltic, the Mediterranean—are under threat from untreated wastes, many of which can feed bacteria and algae; these in turn exhaust the water's oxygen and threaten other forms of marine life. The burning of fossil fuels is increasing, with unforeseeable consequences for the earth's climates and atmosphere. Dust and particles in the atmosphere may also alter the earth's temperature in unpredictable ways. Even the vast oceans, covering 70 per cent of the globe and providing an apparently inexhaustible reserve of moisture, an endless dump for wastes, and a perpetual source of freshening winds and currents, are far more vulnerable to man's polluting activities than had been assumed. Run off into them too many poisons, insecticides, and fertilizers, void too many oil bilges, choke too many of the estuarine waters where the fish spawn and multiply, and even the oceans may cease to serve man's purposes as effortlessly and reliably as he now seems to suppose.

And all these risks are appearing on the human horizon with a world population of less than four billion, at least half of whom have hardly raised their claims on the planet above those of neolithic man. But suppose seven billion try to live like Europeans or Japanese? Suppose they seek American standards of automobile use and add the emission of three and a half billion cars to the carbon monoxide in the air and the lungs? Suppose three-quarters of them move to the cities, seeking there

the developed world's levels of energy use and materials consumption? There is no way in which such equations can be worked out. But in that case, what "gives" on the collision course? Numbers? Yes—but whose? Consumption? Yes—but where? Urban amenities? Yes—but in which lands? Energy slaves? Yes—but not mine. Or does the planet itself, with its precious, irreplaceable, and finite resources of air and water and soil, come under increasing and even irreversible pressure?

In short, the two worlds of man—the biosphere of his inheritance, the technosphere of his creation—are out of balance, indeed potentially in deep conflict. And man is in the middle. This is the hinge of history at which we stand, the door of the future opening on to a crisis more sudden, more global, more inescapable, and more bewildering than any ever encountered by the human species and one which will take decisive shape within the life span of children who are already born.

2 AN UNINTENDED ORDER

The New Knowledge

WHAT BROUGHT mankind to this threshold? In one sense, the forces at work are as old as human society—the search for usable knowledge, the need for production and exchange, the organizing power of the social community. Early clans experimented with pits and snares, captured and shared the game, and followed the leadership of the hunting chief. These three factors—knowledge, economics, political power—became more interrelated, powerful, and self-reinforcing with each advance in technology and organization. What happened after the sixteenth century is that an unprecedented change in the scale of human activity and in the interactions between knowledge, economics, and power produced results which no one foresaw and no one intended.

Take first the question of knowledge. By the seventeenth century an immense corpus of exact and useful knowledge, based upon millennia of observation and practice, already existed in human society. In India and China, in particular, the technical skills needed for the production of textiles, pottery, porcelain, and metal goods were so far ahead of Europe's that the first aim of European merchants since the fourteenth century had been to break the monopoly of Arab merchants and middlemen and trade directly with the fabled Indies and far Cathay.

The sudden surge in knowledge in Western Europe after the sixteenth century cannot therefore be explained by an already established technological pre-eminence—although medieval innovations had been considerable. It was above all a change of approach and method. This development had three fundamental elements. The first was a wholly new emphasis on *useful* knowledge—what Francis Bacon called knowl-

edge "for the benefit and use of man, for the relief of man's estate." Since usefulness implies reliability, the second element was the idea of the repeatable controlled experiment. In this lay the germ of science's master procedure—the movement from hypothesis, an imaginative construction which suggests a solution, to the solidity of proof, which is the hypothesis checked by every test the questing scientist can devise—but still open to further modification or disproof if new facts come up to challenge it. The third element was to devise means of reliability.

René Descartes invented one—the reduction of fields of study to their ultimate components, the "discrete objects" which make them up, irrespective of all the variables of changing situation and context. The other was the exact observation of how objects behaved so that they could be made to behave more usefully. This turned out to imply, above all, measurement. All changes imply the intervention of some force or energy. Things left to themselves continue in the same state. This inertia had long since been remarked by the philosophers. How, then, did material objects change and how could they be made to change in ways determined by man? The idea of utility implied the purposive use of energy. In fact, energy or force can only be defined as "the capacity to produce work." And force, as a capacity to pull, push, lift, drop, and generally move things about, can be precisely measured. The key to controlled use was therefore measurement. As Leonardo da Vinci had prophesied, mathematics would become the key to mechanics and indeed to all the natural sciences.

Energy and Measurement

In the seventeenth century Isaac Newton discovered and measured the gravitational force of the sun and planets in the solar system. Fahrenheit's thermometer gave man the first means of exactly measuring that most ancient of his servants—heat—and opened the way to the precise degree of "cooking" to which materials had to be exposed to produce any chemical alteration and hence any later development of a chemical industry. By measuring steam and putting it to work more exactly, James Watt powered the cotton looms in Lancashire in the eighteenth century and, as it were, formally inaugurated the Industrial Revolution. Sixty years later, steam was adapted to work in moving engines by George Stephenson.

In the nineteenth century, the pace of measurement and successful experiments quickens sharply. There is more exact knowledge from which to begin. The scientists can make larger and more assured raids into unconquered territory, consolidating their work as they advance. We can in particular follow two paths of research which prepared the way for the most Promethean of all human discoveries in the twentieth century—nuclear power.

The first path starts with Descartes's clue of looking for nature's "discrete objects" or ultimate elements. Between 1770 and 1870, a Frenchman, Antoine Lavoisier, an Englishman, John Dalton, and a Russian, Dmitri Mendeleev, managed to discover the constant and relative weights of the whole table of elements—from hydrogen* the first and lightest, to uranium, the ninety-second and heaviest. (Eleven heavier man-made elements have since been added.)

The other path lay through the clarification of the long-noticed fact of electrical energy—the phenomenon of an electric charge passing between positive and negative poles in a gravitational field of force. In the nineteenth century James Clerk Maxwell postulated the passage throughout the whole of space of these charges, "undulations" or pulses. Heinrich Hertz first observed one and Guglielmo Marconi took out the first patent for transmitting a "radio wave" and launched the world on the development of universal instantaneous communication.

But these discoveries did more than bring distant lands and then other planets into audible and—later—visible contact with the earth's inhabitants. The electric pulses could be directed down wires made of good conductive metals like copper, and a massive source of clean, usable, and distributable energy, electricity, came into being. But more than this, when the full range of all the waves in the solar system was finally put together, it was discovered that a vast unified organization of energy existed in the cosmos—the electromagnetic spectrum stretching from electrical household current (with oscillations in the neighborhood of 60 cycles per second), radio and television waves, up through the sounds of speech, the visible spectrum of observable colors, and on to cosmic rays of

*To give some idea of the infinitesimal scale of these ultimate components, one should recall that two hydrogen atoms compose one hydrogen molecule. One ounce equals 8.54×10^{24} (or 8,540,000,000,000,000,000,000,000) molecules. In mathematical shorthand, the small *24* to the right of the ten registers the number of places one moves the decimal point to the right.

such inconceivable energy as to produce 10^{22} cycles per second. From these two master discoveries—the table of elements and the electromagnetic spectrum—there followed in the twentieth century the ultimate breakthrough to the understanding of nuclear structure, the nature of atomic energy, and the beginnings of its use for human purposes in peace and war.

In studying fundamental substances, scientists discovered a number of them—fluorine, then pitchblende, then uranium—which gave off x-rays or radioactive pulses which at 10^{17} to 10^{20} cycles per second were clearly in the upper "solar" end of the spectrum and shared some of the searing power of the sun's own energy. This evidence of near-cosmic power throbbing in the core of supposedly indivisible elements was the clue to the fact that they were not—as had been supposed hitherto—minute, irreducible objects like marbles or billiard balls but immensely complicated electrical phenomena in which electrons orbited continuously round a central nucleus. Moreover, it was discovered that if they were bombarded by other atoms they would disintegrate or unite, giving off immense amounts of energy in the process. From this conclusion it was possible to infer that related processes might be at work at the heart of the sun, releasing the inconceivable floods of energy which powers all moving and living things in the entire solar system. Nuclear power, first exploded on earth at Los Alamos in 1944, brought mankind to the brink of a new meaning to the Promethean myth. Now his fire had in truth been stolen from the sun god and the theft carried with it more than a hint of the primeval curse. Misused for unchecked power and greed, it could bind the modern Prometheus to the lifeless rock in an irradiated planet.

The vast range of scientific achievements that has flowed from the precise measurements of energy and the study of closely delineated "discrete objects" makes up one of the most remarkable odysseys of the human mind. At each new stage of measurement, new kinds of energy were put at man's disposal—steam, then electricity, finally nuclear power. And with each new extension, man's power to manipulate and change "discrete objects" for the relief of man's estate was correspondingly increased. It is difficult to overestimate the degree to which the use of energy and the manipulation of materials has reduced the crushing burdens of physical work, lessened the concentration of human effort on food production, freed men for other pursuits, and extended to millions a wealth and opportunity formerly enjoyed by the smallest elite.

But until relatively recently, the underlying thrust of science's ultra-powerful operations was toward dissection and ever-increasing specialization. New scientific approaches which move within wider fields of relevant relationships—astrophysics, biochemistry, social anthropology—have not yet a full century of practice behind them. The work of synthesis has begun but has not yet offset the risk that emphasizing exact and precisely delineated spheres of study may make too little of the unities and systems underlying, connecting, and in part explaining natural events.

And this fact is closely linked to the dual nature of the scientific enterprise. On the one hand, it is dedicated to the highest standards of objectivity and enslaved to the sternest mistress—the spirit of truth. But once the results are known—the horsepower measured, the atom bombarded, the nucleus split—vastly increased powers of use and misuse fall into men's hands. Energy and matter have, as it were, been torn out of the restraints imposed upon them by the natural system. The molecular structure of material things abstracted for individual use is no longer acted upon by a myriad subtle yet systematic influences of the total environment. Stripped down to its components, it can be made more usable—as in plastic—or infinitely more destructive—as in nerve gas. Nuclear fusion in the sun is shielded from planet Earth by all the intervening layers of atmosphere and cloud cover. On earth, the defenses must be provided by men.

It follows that the missing checks and balances, the lost restraints of the system as a whole, have now to be replaced by human insight and human wisdom. But the truth is that man's tremendous scientific advance over the last three hundred years has been accompanied not by increased insight and wisdom but by equally powerful, uncoordinated, and thrusting developments in economics and politics in the pursuit of goods and the claims of sovereignty. It has not been restraint or reflection that has chiefly presided over the emergence of the new scientific, technological order. To go back to Francis Bacon, the new gods have been "the idols of the market and the idols of the tribe."

From Commerce to Industry

The new technological order is solidly rooted in man's desire for goods and his willingness to work and plan and invest to get them. It is therefore not surprising that a world-wide expansion of commerce

preceded by at least a century the first large-scale technological transformations of agriculture and industry. And very probably the transformations could not have taken place without the stimulus of the new international market.

When one thinks of the extraordinary commercial predominance of the maritime nations of Western Europe in the eighteenth and nineteenth centuries, there is irony in the fact that their earlier drive to trade with the Orient stemmed from a large sense of inferiority—their lack of precious metals and stones, their backwardness in silk-making and porcelain, above all, the total absence of spices to make salted and sometimes stinking meat palatable by the end of the winter.

But the long voyages from Europe to the Spice Islands, to India, and China did more than satisfy Europe's eager contemporary consumer demands. The journeys were distant and risky. They had to be financed long before the homecoming ships, escaping scurvy, pirates, and hidden reefs, could reach port and make handsome profits on Ming China or nutmeg. Loans, credit, interest rates, risk capital, insurance, banking procedures, partnerships, and profit sharing—these prerequisites of the later development of large-scale industrial production were either invented or vastly enlarged by maritime world trade.

When, in the eighteenth century, scientific experimenters of the stamp of James Watt began to put new measurements, tools, and engines into the workshops of traditional ironmasters and weavers, they straightforwardly took over from mercantile practice the techniques of the "long journey"—no longer across distant seas, but across the extended time needed for building a larger factory and assembling a bigger work force. Capital was raised, partners brought in; their contribution paid for all the costs in the construction of the enterprise—the masons, the toolmakers, the bricks and mortar, the interest on borrowed funds. It paid the costs of getting the raw materials and the laborers to the site. It paid the first bills for wages. Then, hopefully, a consumer good—cloth, pans, kettles, pottery—would be ready for the market where consumers were waiting to buy. The price they were willing to pay for the goods had to cover all the previous costs. But the very great increase in productivity —more output for each man-hour of work—made possible mainly by adding steam power to the machines, meant that compared with artisan handicrafts the system began to pour out an enormously increased stream of regular and reliable supplies of consumer goods at reduced

costs—yards of cloth, hammers, pins, cups. The goods could be sold more cheaply, more people would buy them, the costs would be recovered and a profit remain at the end which ambitious spinners or bleachers or cutlers could reinvest in more machines, more output, and more sales. On this balance between increasing supply at lower costs on the one hand, and a widening demand for basic goods on the other—with profit as reward, inducement, and margin for reinvestment—the whole of the early industrial system was built up.

As a decentralized way of satisfying a million different tastes and needs, the market system could hardly be matched. If consumers wanted less, or prices were too high, demand would fall and producers would move out of that line. Eager demand, on the contrary, would send up prices, draw in more producers, and, as a result, send up the output of those goods. Capital would flow to industries which, by satisfying demand more economically, could make the largest margin over cost. By responding promptly to market signals, the whole system would produce, through profit, an increasing surplus for reinvestment. Production would grow, markets widen further, and an expanding balance between supply and demand would bring more and more people within reach of at least a modest affluence. The whole system seemed to have an inner consistency and spontaneous effectiveness which alone could respond to diverse, fluctuating, unpredictable consumer demands and mobilize equally diverse and often uncertain productive resources.

The Price of Prosperity

Yet this immensely powerful expansion of the market, which has steadily gathered momentum for the last two centuries, has also created unintended, fragmented, and destabilizing side effects. The most obvious is the immediate impact on income distribution. If everything were to have a price, expressing a new concept of cost, a whole range of social arrangements designed for a less cost-conscious social order would disappear. The servants, who stood about for prestige's sake in the manor or the merchant's house, were dismissed. Improving farmers—in Britain in the eighteenth century, in Europe in the nineteenth, in Asia in the twentieth century's "Green Revolution"—cleared peasants and cottagers off the land and began to use new productive techniques in order to push up output per acre while cutting labor costs. The safety net of

charity and mutual obligation in the village community broke. The dispossessed moved to the new industrial communities, there to compete wages down to mere subsistence and leave the entire surplus to the wealthy—long established or newly enriched—for reinvestment or for lavish consumption. The social imbalance, the gap between rich and poor, actually widened in the early stages of industrialism—as it still can do in developing societies today.

Moreover, by placing overwhelming emphasis on the sales of goods and the profit to be made from them, the system proved to be deficient in the funds and institutions needed to supply the essential *public* goods —health, education, decent city design, public safety, environmental improvement—which did not offer benefits that could be easily broken down into salable goods and in any case were too expensive for the poorer purchasers. The possibility of what was later to be called "private affluence and public squalor" was present from the beginning in economies so heavily oriented toward the production and exchange of consumer goods.

We can see the effects of this imbalance most clearly in two areas—in the early establishment of what were to come to be accepted as normal industrial costs and in the pattern of the first industrial cities. First, on the side of costs, as the Industrial Revolution gathered momentum two centuries ago, the new managers and owners adopted a concept which was not so much a conscious policy as a response to the risks they foresaw in their untried enterprise. These risks were real enough. A useless invention, a chemical that burned instead of bleached, faulty engines which belied the promise of productivity by running out of steam —these were uncertainties enough without adding extra obligations of environment or welfare. Above all, each experiment—into a new line or a new method—could lead to bankruptcy for oneself, one's family, and one's friends. There was no limited liability in the early days, and nineteenth-century novels are full of dramas of failed banks, absconding clerks, and rascally partners.

To the entrepreneur, therefore, it seemed folly to permit any avoidable costs to be laid to his account. The definition of *costs* in the early industrial system took on a *minimum* content which it has to some extent retained. Costs were what the entrepreneur could not avoid paying. Anything else was left to others or left undone. Untended slag heaps piled up beside the mines and furnaces—some of the size of the tragic

mass at Aberfan in Wales, which more than a century later slid down into the valley and obliterated the village school with the children in it. Industrial effluents were left to flow off in the rivers. The factories belched choking smoke into the air above, and their interiors were as unadorned as economy could make them, nightmares of noise, heat, and danger from throbbing, thrusting, uncaged machines into which pauper workers, often under ten years old, could fall to their death.

Political interventions, such as factory acts and inspectorates, little by little improved internal conditions. But the use of air and waterways as giant sewers for effluents aroused less concern, in part because the scale of industrialization and the flow of consumer goods were not at first so great as to make winds and waters and tides incapable of clearing up a good deal of the mess. Natural systems were treated as "free goods" because they still appeared to be costless cleansers. It is true that a few of the classical economists discussed the problem of what they called "external diseconomies"—one factory's soot dirtying the next factory's windows or upstream chlorine poisoning downstream fish—in other words, the costs an enterprise can cause to others while escaping damage itself. The economists also suggested remedies—fines for delinquent behavior, taxes on effluents. But as late as 1967, one of the world's most widely read economic textbooks discussed such external diseconomies only in footnotes and an appendix.

The insufficiency of the market approach is equally evident in the early growth of the industrial cities. Technology and the market relentlessly speeded up the processes of urbanization. For the first time in human history, the bulk of man's work began to be done not on the land but in built-up areas. It was in the resulting spread of industrial plant and urban settlements that some of the most evident drawbacks of economic expansion guided exclusively by market signals were—and in some cases still are—to be found.

Actually, a tendency to centralize power and order in the new nation-states had begun to blow up the size of the capital cities ahead of technological revolution and market growth. By the sixteenth century, London had 250,000 inhabitants, Milan over 200,000, Antwerp and Amsterdam over 100,000 each. Two centuries later London had nearly a million, Paris over 650,000. But it was this expansion in the cities that began to demonstrate to the new entrepreneurs the value to business of large concentrations of people. A sizable labor force, an accessible mar-

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ket, speedy suppliers—all these cost-reducing elements went into the urban pattern. Industry began to move to the fringes of the largest cities. It built up its own new industrial towns, pushing Manchester from a village of some 12,000 inhabitants in 1717 to a rapidly expanding town of 30,000 only forty years later to a big industrial city of over 300,000 inhabitants by the 1860s.

In these new agglomerations the evils of wastes and effluents were enormously multiplied by concentration. And these were further increased by the poverty and desperate overcrowding of the urban workers. In these first phases of industrialization, labor costs, like all other costs, were held to a minimum. Dispossessed cottagers, handicraft workers put out of business by the new machines, the paupers, the orphans—their competition for jobs saw to it that wages did not do much more than keep alive their malnourished bodies. This poverty in turn determined much of the pattern of housing in the industrial cities. Rents had to match the meager wages. Yet in contemporary philosophy, house-building would be done only if it showed a profit. The solution was crowding. The mean little houses were built back to back in square blocks which permitted the maximum packing in of room space, half of which had access to light only through the door into the front room. In some quarters there were not even wells to provide water. Stinking closets in the basement—or none at all—failed to answer people's sanitary needs. In the streets filth accumulated.

Yet the sheer number of rent-paying families, sometimes one family per room—or per cellar—made profits for landlords and greatly inflated the capital value of urban land, thereby increasing still further the difficulty of expanding the supply of cheap houses. Casual lodgings in which workers slept in the beds in turn—as they still do in Bombay—railway arches, park benches filled in the gap.

In such environments, sickness and death were the visible companions of daily life. Death rates in the cities remained consistently higher than in the countryside and kept a check on the rate of population growth. Choking smoke and pea-soup fog proved lethal to people with respiratory diseases. Typhus and other vermin-spread diseases took a terrible toll in dirty, crowded quarters. The dreaded typhoid spread from the steaming slums to the outer world of middle-class comfort and even into the palaces of royalty.

All these evils of the urban condition set off another decisive trend

in the living habits of modern man. Anyone who could get away from the dirt, disease, and noise of the inner industrial city began to do so. By the middle of the nineteenth century, the move to suburbia was under way. First the villas in their leafy gardens were within reach by horse and carriage—for instance, such early suburbs as Clapham and Hampstead in London, St. Cloud in Paris, or Brooklyn Heights in New York. Then railways allowed for greater distances and the "spread city" composed of people escaping from the central urban core began to move out in waves to ever-further settlements. Thus they tended to re-create the conditions they had tried to avoid. By the end of the century Brooklyn Heights was a city quarter like all the other "first-generation" belts of suburbia. But the spread went on, land values rising to tempt the private landseller and the questing developer and, in some lands, removing the affluent, able to pay rates and taxes, from any role in solving the problems of the older city quarters. The suburban flight thus underlined the condition that Benjamin Disraeli defined in nineteenth-century Britain as the coexistence of "two nations—the nation of the rich and the nation of the poor."

The Consumer Revolution

The evils of early industrialism and the attendant squalor of its urban order were too gross to be accepted without protest and violence. It took more than a century of constant political pressure, ever-renewed efforts of social reform, and some major political revolutions to discredit the idea that an infallible market, simply by responding to a vast variety of consumer signals, could achieve acceptable patterns of income distribution or an adequate level of general welfare. By the second half of the twentieth century, the shape of a new "social contract" had begun to emerge. The role the market should play was either subordinated under socialism to state planning or, in mixed market economies, balanced by a wider acceptance of the community's political responsibility for a whole range of public goods and the citizen's basic right to income, education, work, and welfare.

But, by a paradox, it is precisely this achievement that has created new pressures on the economic system and reinforced the difficulty of a number of earlier problems. A twenty-five-year boom set in among the industrialized nations after 1945. Highly developed consumer goods,

often by-products of war-developed technologies—in energy, in electronics, in transport, in synthetics—added enormously to the range of power-using machines available to the citizen, particularly the automobile. Consumer demand was stimulated in many countries by a new intensity of advertising, the income behind it sustained by the political commitment to economic growth and full employment. This surge of demand began gobbling up resources and increasing requirements of materials and energy at an unprecedented rate. The economy responded rapidly to these signals. New energy-producing equipment, was installed, materials mobilized, sold, used, and junked. World trade doubled each decade. In many countries, the growth of national income was not far behind.

But behind the feverish expansion, old pressures began to gather momentum and new ones were added. In already developed countries, it is true, only certain social groups were desperately poor but their plight was made all the more intolerable by the contrast with the affluence of everyone else. In the world at large, the industrialized powers increased their lead in production and consumption over the ex-colonial, developing lands. In the planet at large, a wealthy "North" in stark contrast to a still-unmodernized "South" transferred Disraeli's dictum to the world community.

The cities once again took the brunt of this contrast—in the pockets of poverty in slums and ghettos in developed lands, in the shantytowns and *favellas,* the *calampas,* and *bidonvilles* which began to surround developing cities with the squalid camps and shelters of millions of migrants from rural misery.

Even where the boom brought rapidly rising and widely diffused prosperity, the pressures increased. A new surge of suburban growth followed the increasing ownership of automobiles. City after city exploded into the surrounding countryside, extending with them the concrete expanses of our vast highways and modern conurbations. Metropolitan areas which had reached a million inhabitants before the First World War went on to grow into conurbations of two and six and seven million.

Moreover, the sheer scale of effluents to be disposed of and materials to be junked—1900 pounds per person per year for instance in the United States—coupled with the wide geographical spread of urban and suburban settlements meant a sudden, vast increase in the strain on air and rivers which, by and large, continued to be used as "free goods" still able,

without cost, to dispose of the unlimited wastes of the millions upon millions of new high-consuming citizens. Nor has this burden simply proved to be an intensification of earlier pollution. It has also changed in character. The very freedom of recently invented technologies to devise, manipulate, and create new substances in the wake of chemical discovery has added a still-unmeasured element of risk to the effluents of massively expanding industrial systems.

But the really new risk, foreseen in the past by only a few of the world's economists, is that such a pressure of rising demand may begin to put intolerable strains on what had appeared to be the planet's limitless resources. This risk had been masked in the thrusting nineteenth century by the opening up of all the planet's temperate lands to European settlement and later by the extraordinary productivity of new forms of energy and chemical transformations. Nor did anyone before 1945 fully foresee the runaway growth in world population.

But once the risks of future shortage begin to appear, the insufficiency of market mechanisms to deal fully with them becomes equally obvious. The market has only one answer to scarcity—to put up the price. In the longer run, this may encourage the invention of alternative technologies which economize materials and energy. But in the short run price rises are usually unavoidable and this fact leads not simply to economic but to political problems. If costs and prices rise, something has to give, either private standards or public spending—or the planet's integrity. For contemporary political systems this dilemma has an extra edge of difficulty in that public spending tends to include a large element of the expenditures which are least useful to consumers and most inflationary in their effect—the cost of armaments. And this is simply one more reminder that, decisive as the market has been as a stimulus to the development of our disturbed, fragmented, and powerful modern order, a far more potent agent of change has been Bacon's other idol, "the idol of the tribe," the emergent nation-state.

Nations and Markets

This third element in the powerful trinity of forces—science, the market, the nation—has its roots in concepts of political sovereignty which in one form or another are as old as the hunting clans. The important point is that the cohesive modern nation-state has developed

the authority, the organization, the will, and the energy to do three critical things.

First of all, it created an internal market, wide yet coherent enough to launch the Industrial Revolution. A nation the size of Britain or France, for example, proved to be a very promising area for commercial organization. It was large enough to create a "critical mass" of demand for rising production but also small enough to be effectively administered and governed. In large, rambling territories like Central Europe with its ill-defined Holy Roman Empire, surcharges and duties would be charged at every toll bridge and city gate. In China, too, distances and local obstacles were too great for the quick emergence of a truly national market. It is significant that of all the nations of Asia, it was in Japan, an ancient island sovereignty most resembling Britain, that nationalism and industry began, in the nineteenth century, to go hand in hand.

Next, the nation states of Western Europe created, without directly intending it, a world-wide market. Europe's maritime powers—Portugal, Holland, Britain, France—first sought trade with Asia and then tried to keep all rivals out precisely because Europe was so short of the consumer goods such as silks and spices men most valued in the past. In the eighteenth and nineteenth centuries, Britain, outdistancing other trading nations, created the first genuinely world-wide system of exchange, exporting African slaves to the New World to produce sugar and later cotton, exchanging the sugar in Europe for iron ore and timber and nautical stores, using the ships to trade for cloth and spice in Asia and paying the Asians with bullion taken from Africa (as the name of the British gold coin *guinea* implies).

This vast entrepôt trade grew more profitable when the collapse of internal authority in India established Britain's colonial control (exercised significantly through a semipublic trading corporation, the East India Company). This takeover permitted the British to phase out Indian hand-loom textiles and substitute Lancashire cloth first at home and then for export—the first modern case of successful import substitution and one which may well have given Britain's textile industry the elbowroom needed to invent full-scale factory production.

This imperial expansion and world-wide commercial predominance was not in any way part of a preconceived plan. It was the very quintessence of the unintended order. But once launched, the type of commercial relations established by Britain and copied by its industrializing

Atlantic neighbors proved remarkably persistent. Basically it involved the exchange of capital and manufactures from developed lands for raw materials produced in developing and often colonial countries. Much the same pattern persists today in the economic relations between developed and developing nations.

The third impact on man's environment flowing from the expansion of national power brought science and state together in the pursuit of war. From the sixteenth to the nineteenth century, the oceans of the world were full of brawling, struggling European rivals, chasing and fighting each other for the control of goods, monopolies, and trading posts. One consequence of this maritime rivalry was to stimulate research into metals light enough to produce cannons which would not sink the ships which had to carry them. Some of the most skillful technical innovators of the eighteenth century owed their head start to naval and military operations. In Britain, for instance, Henry Cort began life as a naval agent and went on to revolutionize iron production. Henry Maudsley, happily remembered for the invention of the beer handle, began his career in machine tools in Woolwich Arsenal.

But it was not only colonial rivalries that powered the furnaces of war. Once Germany, Russia, and Japan belatedly joined the ranks of self-consciously nationalist states and sought to assert their sovereignty and to expand their interests in a world largely controlled by the earlier established nations, nationalist rivalries exploded into a series of wars which in the twentieth century twice engulfed the planet and still leave behind such powerful legacies of fear and distrust that they inspire a general spending on armaments on the order of $200 billion a year.

If the modest wars of the seventeenth and eighteenth centuries sparked a genuine acceleration in technological skills, it can be imagined what the twentieth century's global wars and global arms have brought about in the way of thrusting, single-minded technical discovery and applied research. It was the nineteenth century demand for accurate small arms that encouraged the industrial evolution of interchangeable parts and the high-speed lathes, new drilling equipment, hardened metals, and new alloys needed to make them. All these inventions have proved critical in the development of mass-produced modern "consumer durables," above all the motorcar.

The First World War gave agriculture the tractor via the tank and put a booster of incalculable force under the automobile and the airplane.

The Second World War speeded up by decades the evolution of all kinds of electronic equipment and ushered in the final Promethean theft—the discovery that the atom's nucleus could be split and its earth-destroying power used for human purposes. And all this war-inspired stimulus, all this investment, all this input of trained minds and infinitely elaborate equipment into weapons has served the most negative, the most divisive, the most wasteful set of purposes that mankind can set itself—and at an incalculable price in welfare and resources.

In short, mankind has still found no organized system for reconciling the driving demands and ambitions of national statehood with the wider unities of a shared planet. With all the growth, all the enrichment, all the apparent market success of the fifties and sixties, men are left in deep unease about the current condition of their planet.

Just as the grouping together of factories in urban concentrations during the last century vastly increased the pressures of filth and contamination, in our modern mass economy the sheer concentration of consumers is beginning to show a comparable effect. Drainage systems, waste disposals, urban structures—none was designed for such a flood of disposable artifacts bought, enjoyed, and thrown out by such a flood of people.

Above all, the distribution of prosperity is dangerously skewed. Within each affluent economy, minorities who are handicapped by ethnic prejudice or age or sickness tend to be left behind to observe vicariously on television how the luckier three-quarters live. And in planetary society as a whole, it is three-quarters who live badly and, as their numbers rise, face bleak prospects of living better.

To restore balance and hope, to moderate the despairs and pressures, to achieve common policies for a viable political order are thus the preconditions of any decent human environment on planet Earth.

If all man can offer to the decades ahead is the same combination of scientific drive, economic cupidity, and national arrogance, then we cannot rate very highly the chances of reaching the year 2000 with our planet still functioning safely and our humanity securely preserved.

Equally, however, a careful recognition of where our failures lie is the first step toward the wisdom and restraint our overwhelming power requires of us. In every case, the needed steps take us away from division, from single-shot interventions, separatist tendencies, and driving ambitions and greeds. We have to grasp and foster more fully the truly

integrative aspects of science. We have to revise our economic management—of incomes, of environments, of cities. We have to place what is valuable in nationalism within the framework of a political world order that is morally and socially responsible as well as physically one. Our errors point to our cures and on the basis of man's survival up to this point, it is not wholly irrational to believe that he can learn from his mistakes.

Part Five: A Planetary Order

13 THE SHARED BIOSPHERE

Airs and Climates

NOWHERE IS THE vulnerability and interdependence of the total biosphere more evident than in the envelope of atmosphere upon which more and more of industrial man's activities are beginning to impinge. It is, of course, alien to our thinking that the firmament itself could be vulnerable to our intrusions. Yet there can be a useful corrective to this kind of thinking in a return, for a moment, to our knowledge of the alphabets of space and time—of the electromagnetic spectrum and the earth's evolution through the billennia. Let us recall the solar-shield effect of the earth's atmosphere. Over the ages, the general level of heat in the planet has been maintained with fair uniformity by a critical balance. Incoming solar radiation, coupled with the earth's own reabsorption of the heat it gives off itself, just about equals the amount of radiation that is blocked en route from the sun or sent from cloud and earth surfaces back into space.

Different parts of the planet are, obviously, warmed and cooled in different degrees and their interchanges—through the winds and air currents and the universal mediations of the ocean—make up the whole, totally interdependent climate of our planet. In the tropics, more heat is absorbed than in the highly reflective polar regions. The heat generated in the center tends to flow to the poles and their cooler airs are drawn back toward the center. The general effect is to mitigate extremes of temperature. But this relatively straightforward motion is immensely complicated by the spinning of the earth on its axis, by the massing together of land in some areas, of water in others, by high mountain ranges, and the distribution of rain forests and deserts. With so many

variables, it is not surprising that local weather systems exhibit very large variations round expected norms. It is perhaps equally unsurprising that the whole global climate can itself undergo profound modifications.

During about 90 per cent of its stable existence, our planet appears to have had no ice at all at the poles. But we know from the evidence of geology that it has undergone some five or six periods of glaciation. We appear to be in the tail end of the latest—the Pleistocene Ice Age, which lasted over a million years and brought the glaciers to the Mediterranean. Today, the ice has retreated, but is not quite back to normal. Yet so great is the immediate effect of the ice caps on our global climate that "normal"—in other words, no ice caps—could mean a catastrophically different topography, with some land masses under water and others indescribably hot.

Clearly man has had nothing to do with these vast climatic changes in the past. And from the scale of the energy systems involved, it would seem rational to suppose that he is not likely to affect them in the future. But here we encounter the other facet of our planetary life: the fragility of the balances through which the natural world that we know survives. In the field of climate, the sun's radiations, the earth's emissions, the universal influence of the oceans, and the impact of the ice are unquestionably vast and beyond any direct influence on the part of man. But the *balance* between incoming and outgoing radiation, the interplay of forces which preserves the average global level of temperature appear to be so even, so precise, that only the slightest shift in the energy balance could disrupt the whole system. It takes only the smallest movement at its fulcrum to swing a seesaw out of the horizontal. It may require only a very small percentage of change in the planet's balance of energy to modify average temperatures by 2°C. Downward, this is another ice age; upward, a return to an ice-free age. In either case, the effects are global and catastrophic.

Scientists are, therefore, turning their attention to the points at which human actions, however minuscule their effects may seem when set against the total scale of the planet's energy system, may nonetheless trigger off one of those small but fateful changes which alter the balance of the seesaw.

Among the enormous range of technological man's activities, three such points of leverage seem serious enough to arouse real concern. The first turns on the role of carbon dioxide in intercepting the earth's heat

radiations and in transmitting them back to the earth, the so-called greenhouse effect. Its action is rather like the effect of car windows when the sun's rays enter the car and warm up the seats and fittings inside. But glass does not pass on heat. It lets the rays through but retains the heat within the interior of the car, which gets hotter and hotter. In the atmosphere, carbon dioxide can have the effect of glass. It can cut down the rate of surface cooling and we do not know whether its effects are reversible. In normal amounts—the .03 per cent of the total atmosphere —it plays a very small, though specialized, part in the earth's heating system. But there is evidence to suggest that over the last decade, the release of carbon dioxide into the atmosphere as a result of man's burning fossil fuels has been increasing by 0.2 per cent a year. We simply do not know where all the carbon dioxide produced in the biosphere year by year actually goes. Perhaps half is absorbed in the oceans and the metabolism of plants. But the increasing concentration in the air means that, at present rates of use, the earth's temperature could rise by 0.5°C by the year 2000.

But present rates may well increase. Excessive deforestation can reduce the rate of natural removal of carbon dioxide from the atmosphere through the action of leaves. At the same time ever greater amounts are being pumped into the atmosphere as industrialization goes forward. The energy demands of developed societies are still rising sharply. Projections of power demands in the developing world suggest even more precipitous increases. What would be the consequences of multiplying energy consumption in the developing nations to the levels obtaining in technological societies? We do not have to postulate the fantasy of three and a half billion cars on the planet to begin to wonder whether the sum of all likely fossil-fuel demands in the early decades of the next century might not greatly increase the emission of carbon dioxide into the atmosphere and by doing so bring up average surface temperature uncomfortably close to that rise of 2°C which might set in motion the long-term warming up of the planet.

The risk is increased by the possibility that a change of this kind could conceivably be working with and thus reinforcing an underlying global movement already taking place independently of man. Recently scientists have extracted long cores from the Greenland ice cap and constructed from their variations in freezing and melting a sort of profile of an ice age. The last two are found to resemble each other to a marked

degree—the change from major glaciation back to ice-free conditions being marked by a series of remarkably similar wobbles back and forth between more freezing and less freezing. It is not therefore irrational to wonder whether a massive man-induced increase in the atmosphere's carbon dioxide, coinciding with one of nature's own warmings up, might not change a slight move at the center of the seesaw into a violent shifting of weight and the risk of major and unpredictable global consequences.

Another range of risks is incurred by industrial man's increasing emission of dust, soot, and gas, which combine with each other and with droplets of vapor to thicken up the atmosphere and increase the earth's cloud cover. The higher the altitude of these concentrations, the more lasting they appear to become. Particles which would vanish in a few weeks in the lower airs can last from one to three years in the high altitudes. There is already evidence that cirrus clouds are increasing along the most-used air routes in the northern hemisphere and that the earth's cloud cover as a whole is showing some signs of deepening. The difficulty is to know what effects such changes might have. If they effectively reduced the passage of the sun's radiation, they might lower the earth's temperatures. If, on the contrary, they reflect back the earth's own emissions of heat, they reinforce the greenhouse effect.

Scientists have some evidence to go on. In 1963, Mount Agung blew up, taking a sizable piece of Bali with it. Like the great explosion of Krakatoa in 1883, the Agung eruption filled the lower stratosphere with particles which dyed the sunsets with light-reflecting particles. The effects persisted for several years and had world-wide consequences within six months of the event. The band of the stratosphere lying above the equator was heated up by 6° to 7°C immediately after the eruption and remained 2° to 3° higher for several years. There is thus no doubt that gases and particles in the stratosphere do hang about, do have world-wide effects, and do raise the temperature. They may do other things—combine in unpredictable ways with each other under the direct, almost unshielded influence of the sun's radiation. A sort of photochemical effect like smog is conceivable. It has also been suggested that nitrates and sulfates from volcanoes—or supersonic exhausts—can unite with the critical supply of ozone and deplete the upper atmosphere of one of the essential elements in the planet's antiradiation shield.

It is, incidentally, this uncertainty over the cumulative effects of carbon dioxide, particulate matter, vapor, and gases in the atmosphere

that has led some scientists to advocate caution in any massive development of supersonic transport. But virtually all scientists would agree on two propositions. Industrial man, by using the air as a giant sewer, can have profound and unforeseen effects on the earth's climate and thus the possible consequences will be borne not simply by the polluting agencies, but by the biosphere as a whole. From this follows the second point. We need far more knowledge, far more sophisticated simulation of climatic effects on giant computers, far more monitoring on a global basis, far more exact information on what we are actually doing in the atmosphere that the whole of mankind must share.

All these concerns with global air pollution lie beyond the effective protection of individual governments. It is no use one nation checking its energy use to keep the ice caps in place if no other government joins in. It is no use the developed nations suggesting lower energy use just at the moment when the developing nations see increased use as their only exit from the trap of poverty. The global interdependence of man's airs and climates is such that local decisions are simply inadequate. Even the sum of all local separate decisions, wisely made, may not be a sufficient safeguard and it would take a bold optimist to assume such general wisdom. Man's global interdependence begins to require, in these fields, a new capacity for global decision-making and global care. It requires coordinating powers for monitoring and research. It means new conventions to draw up ground rules to control emissions from aircraft and to assess supersonic experiments. It requires a new commitment to global responsibilities. Equally, it needs effective action among the nations to make responsibility a fact. And all these necessities—for more research, better monitoring, stricter control, and more global action—are simply reinforced when we turn to man's other universal environment—the world of the seas and oceans.

The Oceans

Only the fact that so much of the surface of our planet is composed of water makes it habitable. And, in the view of many marine biologists, the oceans are the most immediately threatened part of the biosphere.

It was in the oceans, after the secular downpour of the early rains, that life first began to stir, shielded by the waters from the sun's irresistible radiation. It was from the oceans that plants and animals emerged

to colonize the land surface of the planet. It is the oceans today that provide the water vapor which, drawn up by the sun, falls upon the earth in harvest-bringing, life-sustaining rain. Ocean water is our planet's filtering system where all debris, both mineral and biological, is dissolved, decomposed, and transformed into life-supporting substances. It is the universal global sink, a vast septic tank from which clean water returns to man, beast, and plants by way of evaporation and precipitation. It is a major provider of the oxygen released by its phytoplankton for the benefit of all the species of land, air, and sea—breathing with lungs and gills. Without water's special qualities for holding heat, much of the earth would be uninhabitable. The oceans are the coolants of the tropics, the bringers of warm currents to cold regions, the universal moderators of temperature throughout the globe.

In more mundane ways, too, the oceans are indispensable to man. For good and ill, they first created the world-wide currents of seaborne trade which, since the fifteenth century, have steadily drawn our planet into a single economic system. And they still produce, for the globe's rising population, a vast harvest of indispensable protein. In 1969, 63 million metric tons of fish came from the sea. This is estimated to be only approximately one-fifth of the oceans' production. But most of it is deeper than can be fished economically with present equipment. Even so, the seas' fish harvest within its present rate of productivity could perhaps be tripled and an added 100 million tons, properly distributed, could provide some 20 million extra tons of protein annually to offset the deficiency which threatens so many of the planet's children over the next three decades.

Incidentally, one of the world economy's most unacceptable diversions of resources is that at least 50 per cent of the fish catch which today is converted to fish meal ends up feeding pigs and chickens in developed lands. If turned directly to human use, fish could make up part of a protein diet for the world's children at an annual cost of no more than $8 a child. Thirty years ago, only 10 per cent of the fish catch was diverted from human consumption. It is a sobering commentary on the humanity of our world economy that "developed" animal pets have the chance of a better diet than all too many "developing" babies.

As in the airs and climates, the ocean system must seem, at first thought, to be infinitely beyond the reach of man's puny influence. Whether we see it as the sacral cleanser of "Earth's human shores" or

the cruel "widowmaker" of a million shipwrecks, hurricanes, and typhoons, it is restlessly powerful, serenely or menacingly indifferent to all the busy activities men seek to pursue in and under its buoyant, treacherous waves.

In fact, men are still under the strong influence of the medieval concept of an endless ocean. We all tend to feel that once a polluted river empties into the open sea, once we conduct city sewer systems far enough away from land, all industrial and urban discharge will disappear somehow into blue space beyond the horizon, as if we pipe it away from our own planet. We seem in this conception of the ocean to forget for a moment that the world is round and without edges. The first and only refuse man has ever disposed of outside his own biosphere is what was recently parked on the moon. Every ounce hitherto dumped or channeled into the sea, from the very morning of time until the modern age of general industrialization, has accumulated in one form or another inside the same landlocked sea, the lowest section of our biosphere and the only one with no outlet for refuse. Standing on the beach gazing toward the horizon where blue sea runs into blue space, we have not quite digested the message from the countless twentieth-century voyagers who, every year, cross the ocean from continent to continent, or the astronauts who see the whole planet from above, all giving their witness that the ocean has none of the infinitude we give it in our dreams.

Lake Erie is grossly polluted, to a level one would have thought impossible a few decades ago. Take ten Lake Eries and place them end to end and they will span the Atlantic Ocean. But the ocean is much deeper and spreads in all directions, we may reply. Yes, but Lake Erie has an ever-running outlet and hardly half a dozen major cities to pollute it. The ocean, however, daily receives and never returns the outlet from Lake Erie and thousands of other polluted lakes and rivers all over the world, and directly or indirectly the sewers and fallout from all the world's countless cities and all farmlands and all the industry. Instead of running into blue space, the oceans are landlocked and, if we go far enough in any direction, they are completely interlocked and share the rapidly accumulating pollution among them.

To this we must add that the waters most important to man are those most rapidly polluted: the layer nearest the surface and the coastal and estuarine zones. The bulk of plankton and other marine life dependent on photosynthesis is concentrated in an upper layer of ocean water no

deeper than the great lakes. In fact, about 80 per cent of the world's fish catch is derived from waters less than 200 meters deep, which corresponds to half the depth of Lake Superior. Again, this concentration of biological life near the surface is further amplified next to land. An estimated 90 per cent of all marine life is concentrated above the continental shelves, which represent only about 10 per cent of the total ocean area. Plankton and fish indispensable for life on earth are thus concentrated in the ocean water most vulnerable to man's activities. There are fish outside and below these areas of high concentration, but in greatly reduced quantities, and also below the reach of nets; 1000 meters is fairly generally held to be the outside commercial limit.

Thus, while we have to readjust drastically our erroneous conception of an endless ocean invulnerable to the combined refuse of all men on earth, we must also face the fact that there are leverage points, areas near the surface and near the coasts in which human actions very soon can become sufficiently concerted to have lasting destructive effects. Even deep-sea species are dependent on the exposed coastal zones.

Estuaries and shorelines are almost without exception the spawning grounds for fish, some of which migrate over vast distances to swim back up the same rivers when spawning time returns. It is also at the level where land and sea meet that the most hopeful areas lie for any very great increase in "managed" fish cultures with the purposeful use of nutrients and heat to increase the fish catch in a systematic way. Shellfish, for instance, can be encouraged to double their output if the velocity of water round their beds can be increased. Hot water effluents from power stations, which damage some kinds of marine life, can be helpful to others. Shrimp harvests, for instance, appear to be responding to a managed use of heat.

Coastal waters are not only useful to man for food. They provide him with some of his favorite recreations. The annual day at the seaside was the supreme break from nineteenth-century dirt and toil. Two weeks on a packaged tour to Majorca or the Black Sea are the modern equivalents. Swimming, boating, skin diving, speedboating, fishing—the millions upon millions of tourists who get into motion as summer comes on usually end up with one toe in salt water. As leisure increases, the seas' importance for vacationers grows in the same degree.

And it is precisely the coasts and estuarine waters that are becoming steadily less usable for human purposes. Whatever awe man may feel at

the majesty and magnificence of his planet's seascapes, he goes on treating the ocean as a sewer. In many lands there are heavy concentrations of population near the sea. A very large part of domestic sewage is simply dumped directly into the sea with minimal or no treatment. In addition, industry contributes a steady quota of heavy metals, inorganic materials, and, on occasion, radioactive waste. Rivers, too, add their effluents whenever, as is the common practice, they have been used as drains.

Rivers also bring down some of the run-off from fertilizers. And pesticides used in agriculture, above all, the chlorinated hydrocarbons, such as DDT, are carried out to the ocean, where, following the currents and concentrating as they go up the marine food chain, they affect animals even in the areas most remote from agricultural activity, like the polar regions. Chlorinated hydrocarbons sprayed by man as pesticides in farmlands turn up producing unhatchable eggs from the bald eagle, the peregrine falcon, and other species. They accumulate in the organs of polar bears. When twenty whales born and bred in the east Greenland current coming from the North Pole were recently harpooned for test purposes, six identifiable pesticides including DDT were found in the blubber of all of them.

Apart from the toxic influx of global range, other pollutants have roughly the same effect on coastal waters as they have in rivers and lakes. The nutrients from domestic sewage and agricultural wastes tend to overfertilize inshore waters. Blooms of marine plants become more frequent. A mixture of sewage and fertilizer run-off increased the bacteria count in New York Harbor ten times over between the late fifties and the late sixties. Where discharges take place into closed seas like the Baltic and the Mediterranean, there is real risk of producing permanently anaerobic conditions, in other words, such a lack of oxygen that only foul-smelling marsh plants and animal life can finally survive. When in 1971 many Italian resorts had to close their beaches for fear of widespread hepatitis, they only gave a preview of what might become the Mediterranean's universal condition after another decade of inadequate sewage treatment.

It is all too often the coasts which chiefly suffer from the pollutions caused by the drilling and transport of oil and from the even larger burdens brought to the seas and rivers in industrialized areas. Underwater drilling for oil is steadily increasing on the continental shelves. Even if, hitherto, disasters such as the massive oil leak in the Santa Barbara

Channel are rare, the expansion of underwater operations may increase the risk of more frequent mishaps in the future. So far, underwater drilling is largely carried out by techniques adapted from land-based procedures; blowouts do occur in land drills, but they do so with far less disastrous consequences than would be the case in coastal waters which could spread the pollutants with every force of wind and tide and current. At present, only 17 per cent of the world's oil supplies come from offshore drillings. By 1980, offshore production is expected to rise to 50 per cent of the oil produced from all sources in 1970. Such rapid expansion carries with it a danger of more frequent spills, more fouled beaches, more depletion of estuarine hatcheries, more birds and fishes dead in the slicks of oil.

It is also, as the disaster of the *Torrey Canyon* so visibly illustrated, in coastal waters that there is the greatest risk of groundings and collisions of tankers which release oil to the seas and beaches. Nearly all the major tanker routes lie inshore—the Persian Gulf, the Mediterranean, the western waters of Europe, the eastern waters of North America. The estimates of how much oil reaches the oceans from passing tankers, drilling rigs, and coastal installations have varied from 1 to 10 million tons annually but an expert group reporting to the Secretary General of the United Nations recently estimated that 2 million tons are reaching the oceans every year despite conventions regulating oil emissions.

Another possible danger lies in the astonishing growth in the proposed size of tankers. Only five years ago, the average tanker was 12,000 to 13,000 tons. There are now four tankers in operation of 325,000 tons. Future plans point to monsters of 800,000 tons. A single disaster with one of these giants releasing all its oil would increase by 25 per cent the total pollution of the seas in that year. On the other hand, given the shortage of skilled crews and the fact that large tankers can absorb the cost of sophisticated oil-handling equipment, there is a case to be made for the possibility that larger tankers will be better serviced and so consequently safer than smaller ones.

Since 1964, major progress in restraining pollution from tanker operation has been achieved with the development of the "load on top" system. Tankers returning from their delivery point normally carry a ballast of sea water and clean their tanks and bilges at sea. The previous practice was for tankers nearing the end of their return voyage to discharge their ballast—oily wastes, sludge, and all—into the sea. Now, equipment on

board and new facilities in port allow tanks to be cleaned at sea and the residues off-loaded on return to harbor. The ballast must still be discharged at sea, but with far less pollution—how much less depending on factors like the length of voyage, temperature, and efficiency of the crew. The adoption of this procedure by 80 per cent of the world's tanker fleet has reduced the amount of oil intentionally discharged into the ocean by 2 to 3 million tons a year. Extension of this practice to the rest of the world fleet could reduce the current 1 million tons deliberately discharged to a theoretical minimum of about 100,000 tons.

Oil pollution is more than a coastal problem. It is a consequence of the fact that man uses the whole oceans as a receptacle for unwanted materials and wastes. Here we confront a difficulty. We do not know how much is being poured into the oceans. We do not know how much they can stand. At least, in coastal areas, we can see—and smell—a clear and present danger and make some estimates of the costs of the damage and the expenditures needed to remedy them. The British taxpayer has some idea of how many millions he had to pay to clean up after the *Torrey Canyon.* Hoteliers can estimate their losses as beaches close in the wake of hepatitis. A balance sheet can be roughly drawn up between the decline in salmon and the rise in shrimps—although salmon's migratory habits make this a devious international calculus of profit and loss. But once we get away from the shores and from reasonably measurable and observable effects, we enter a world almost as dark as the ocean deeps.

Now it is perfectly true that nature itself uses the oceans as a dump. Every year the rivers of the world wash down into the oceans enormous quantities of minerals which are diluted or oxidized on the surface or sink to the bottom. Estimates made in the mid-sixties suggest that every year, nature, by its own unaided efforts, flushes some 25 million metric tons of iron into the seas and between 300,000 and 400,000 tons of manganese, copper, and zinc. In addition, lead and phosphorus each provide 180,000 tons and mercury 3,000 tons. The point about these last three elements is their toxic effect. Lead and mercury are lethal poisons; phosphorus contributes to algae blooms. To these natural flows we must now add the vast and accelerated run-off from modern technology. This inevitably increases greatly the flow of minerals to the final dump of the ocean. And these levels prevail at a time when only one-third of humanity has fully entered the industrial era. Extrapolations of comparable output and run-off to match rising world activity would mean a

sobering amount of toxic substances in the oceans by the year 2000, simply as a likely by-product of the more or less casual disposal of industrial wastes.

And to this we must add the very far from casual dumping to which the oceans are exposed. Once again, we are in very great darkness. Every now and then a sensational fish kill reveals that old canisters full of mustard gas have at last eroded as a legacy of the First World War. The much-publicized dumping by the United States Army of containers of deadly nerve gas off the Bahamas in 1970 is remarkable chiefly for that publicity. One may wonder whether all military establishments resist the temptation to dump their poisons under the cloak of national security.

But this is not simply a military game. Some municipalities regularly dump their sewage in nearby stretches of international water. New York City has created a "dead sea" at the approaches to the harbor by dumping massive amounts of sewage sludge there for the last two decades.

As nuclear power generation increases, most nuclear nations are likely to drop into the oceans more of those hopefully secure stainless-steel containers loaded with radioactive wastes. But a lot of industrial dumping is much more casual. In 1970 only the alertness of the official maritime authorities in Norway exposed the practice of a number of European plastics manufacturers of dropping their most poisonous effluents in containers in the North Sea.

Nor is secrecy the only source of ignorance. We still know very little about the processes by which the oceans detoxify, evaporate, or absorb the massive wastes which flow into them. The various components of oil, for instance, differ greatly in durability and toxic effect. They differ too, in their response to temperature. Heat and oxidation are prime factors in dispersing oil's by-products. But in Arctic regions, frozen waters and sub-zero air may keep oil spills or leakages intact for half a century. We also know little about the deeper movements of currents in the oceans. It is not impossible that canisters of poisonous toxins disposed of in supposedly safe ocean trenches and deeps may, for all we know, be swirled across the ocean floors to end up, broken and leaking, on the rocky coasts of distant continents.

There is, in short, no escape from the underlying unity and interconnection of man's ocean world. Seas and oceans, like the airs above, mingle with each other, pass on each other's burdens, cleanse or poison each other, move in steady currents and unpredictable tempests to weave

a seamless watery web. Their rains fall on the just and unjust. Their tides sweep every human shore. Sovereign governments may proclaim their sovereign national control over their own territories. But the airs bring in the acid rain. The oceans roll in the toxic substances. Pollution moves from continent to continent. And what is territorial water off Peru today becomes territorial water off Polynesia a few weeks hence. It is, above all, at the edge of the sea that the pretensions of sovereignty cease and the fact of a shared biosphere begins, more strongly with each passing decade, to assert its inescapable reality.

The governments' response to this imperative has been to move hesitantly into limited conventions and agreements with other nations to lessen the risks of degrading the oceans. The examples are beginning to multiply. Take, first of all, the question of pollution by oil. The nations have taken some preliminary steps to check it. The International Maritime Consultative Organization (IMCO) has been instrumental in working out a Convention for the Prevention of Pollution of the Sea by Oil, negotiated in 1954 and amended in 1962, limiting the rights of ships to discharge oil, prescribing safety features for vessels, and providing for rights of inspection. In 1958, two conventions, on the High Seas and the Continental Shelf, included provisions to keep oil from damaging the marine environment. Then in 1969, in the aftermath of the *Torrey Canyon* disaster, further conventions were negotiated—the Brussels Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualties and the Convention on Civil Liabiiity for Oil Pollution Damage.

In two related areas of possible pollution—the disposal of radioactive wastes and the dumping of toxic chemicals—the need for international action is also recognized and beginning to emerge. At present, the number of states conducting nuclear programs and facing a problem in the disposal of radioactive wastes is very small. The United States has recently discontinued the practice of disposing of radioactive wastes at sea. But by 1980 the world output of nuclear energy may be ten times larger than it is today and a dozen or more nations may have begun production of power from nuclear reactors. The International Atomic Energy Agency has started, under the general authority of the 1958 High Seas Convention, to lay down standards for the disposal of nuclear wastes in the sea, for the safe transport of radioactive materials, for the surveying and monitoring levels of radioactivity, and for safety regulations in ports

and approaches used by nuclear merchant vessels. So far no regulatory actions have been taken, but on a regional level, the European Nuclear Energy Agency has supervised the dumping of radioactive wastes.

A similar process has been set in motion to cover the disposal of toxic chemicals. A Convention on the Control of Marine Pollution by Dumping from Ships and Aircrafts, banning the dumping of some substances and controlling others, has been prepared for adherence by nations bordering the northeastern Atlantic. A proposed international convention would forbid dumping of toxic wastes at sea without a governmental permit which would be issued only after a full statement of the nature of the wastes, their volume, the proposed methods of transportation, and the place where dumping is to take place. The information would, in addition, be passed on to a central international register so that the basis would exist for a continuous check on the scale of toxicity of the materials the oceans are being compelled to absorb. Such a register is, incidentally, still lacking for international dumping of oil from bilges and for the disposal of atomic wastes.

The limitations in these arrangements are clear enough. They all depend upon the voluntary cooperation of governments in imposing standards on their citizens. Better safety regulations and higher insurance—like superior navigational aids or better standards for the ship's crew—cost more money. There is thus a standing temptation to shipping companies to cut corners and costs and in this way gain a competitive advantage. In fact, the existence of "flags of convenience" by which shipowners register with Panama, Honduras, and Liberia precisely to avoid national regulations—the *Torrey Canyon* had Liberian registration —does not exactly promise total compliance with international standards. Indeed, more than ten years after the drawing up of the various conventions regulating oil emissions, as we have seen, at least two million tons of oil are still leaked to the sea each year.

For this reason, some governments are considering more seriously means of using both carrots and sticks—positive actions to get a better control of oceanic pollution, more effective deterrents against antiplanetary behavior. On the positive side there is, for instance, clearly scope for joint international action to move in, in a concerted way, on any large oil spill. Although no means are yet in sight for cleaning up the diffused global drift of oil clots from routine tank washings, methods and devices are being introduced by some nations to fight concentrated oil spills due

to accidents. The Soviet Union has developed a special ship which is capable of skimming 7 tons an hour off the surface of the water. The Americans are working on an Air-Deliverable Transfer System complete with portable pumps and huge plastic bladders to contain the slicks. This can, apparently, go into operation within four hours of receiving a distress call and pump out 20,000 tons of oil within twenty-four hours of the signal. Such systems could be situated at strategic points along the oil routes and be ready on call. The suggestion has been made that their costs might be covered by a world insurance system. In this way, poor countries with coastlines as exposed as any other to the risk of massive pollution would not have to foot an impossible bill in cleaning up the mess.

This possibility is enhanced by another international development—the use of satellites as navigational guides. A ship in presatellite days would be lucky if it could get within a half mile of reporting its correct position. Now the pinpointing is so exact that men can return from the moon and splash down within a mile of the waiting helicopters. Accidental spills could be as exactly located and then speedily attacked. In fact, the question is beginning to be asked whether the international community would not be wise to transfer to the major trade routes the system now operating in the air—of traffic corridors into which craft come and then vary their pace only on permission from ground control. It has now been agreed that, in such an area of total congestion as the English Channel, ships must observe specific shipping lanes. The principle could be capable of useful extension. Moreover, satellite observers may before long be in a position to identify and photograph delinquent dumping of all kinds.

These activities have led to increasing interest in the possibility of some kind of international authority which could, on behalf of governments, oversee safety controls, set in motion disaster operations, and exercise a general policing function to see that ships do in fact obey the regulations laid down in the international conventions to which governments have agreed. Since there is no sovereignty over the oceans—outside the ominously growing "national waters"—an authority of the kind discussed could preserve the largest and least divisible part of man's planetary inheritance from the tribal squabbles and national divisions which have wasted, ruined, and soaked in blood so much of his territorial patrimony.

More comprehensive proposals have in fact been put forward to vest an international authority with supervisory rights over all waters beyond the depth of 200 meters and to include in those rights control over the seabed, supervision of the disarmament proposals already agreed for it, and perhaps disposal of whatever riches may be found there later. On this last point conflicts have arisen between states that wish to secure for themselves the minerals that may lie on contiguous continental shelves beyond the 200-meter line and the wider proposal that the potential wealth be held in trust f all the developing peoples. As methods of deep-sea mining extend the range of possible extraction, the division could become more acute. There is, therefore, all the more reason for reaching international agreement on jurisdiction before further advances to take over the last remaining areas in which the seamless web of air and water, of moving currents and great tides still lives and moves in its fundamental unity, still able to serve not this or that divisive interest by the common needs of all mankind.

The importance of this issue to the whole question of a workable planetary system can be underlined by reference to another potential area of responsibility for a possible maritime authority—monitoring the oceans from a series of regional research stations, with universally accepted standards and with total availability of the results to all governments, research bodies, and citizen groups. As we have seen, both with radioactive wastes and with dumping, we do not know the cumulative effect of what we are doing. It may seem inconceivable that a system as vast as the planet's interconnected seas, covering 70 per cent of the earth's surface and in constant interchange with the atmosphere and with the land masses about it, could ever be vitally or irreversibly affected by human activities. But an international body of marine biologists assembled at the 1971 Pacem in Maribus Conference concluded unanimously that marine life was in serious danger of destruction by pollution. Just as the balance in the atmosphere between planetary heating up and planetary cooling down is incredibly delicate, it may be that among the thermal exchanges of the great currents or the trace elements of critical minerals or the unimpeded living and breathing of minute phytoplankton, there are thresholds of stability which man could cross only at the risk of disaster. We are ignorant of all this. But as the weight we impose on both our airs and oceans steadily increases—the effluents, the transport, the recreation, the sheer pressure of multiplying populations—we

have to know. And one of the principal ways in which a useful and reliable body of knowledge can be built up is by a very great increase in atmosphere and oceanic monitoring and by provision for international teams of experts to assess and interpret the facts on both global and regional bases.

The need for internationalizing such procedures was brought out clearly in the summer of 1971 when the Working Group on Marine Pollution met in London to prepare proposals for the Stockholm Conference on the Human Environment. At that meeting, eleven developing nations, drawn from Latin America, Africa, and Asia, called for a Third World monitoring system on the grounds that any research or survey of world-wide pollutants conducted by already developed powers could evolve into a further means of trade control and protectionism.

This is part of a wider concern. The first imperative for most developing countries is still for modernization and growth. This permanent need requires all the resources available for local use and developing countries are not likely to welcome the possibility of having to share in the cost of cleaning up oceanic pollutions they did not create. Moreover, development requires larger opportunities for international trade, not more restraints. Some developing governments fear that tighter environmental controls might be used as further barriers to their overseas sales.

How do we know, they argue, that this new concern with the environment is an honest one? We have seen our exports of foodstuffs excluded from developed markets on what has often seemed to us dubious, locally determined rules about sanitary standards. Will the risk of DDT now be used in the same way? Will standards of environmental control which we, as underindustrialized countries, do not yet require be made the precondition of admitting our exports? Will the development of local shipping be made even more impossibly expensive by the imposition of insurance costs and antipollution devices to clean up oceans which richer nations have corrupted for half a century without a thought for the environment? And if standards are not observed, are we as developing nations likely to find harbors closed to us and a new range of nontariff barriers put in the way of our exports, which represent less than 20 per cent of world trade and, in manufactures, less than 5 per cent?

The fact that the developed nations' increased interest in the human environment has coincided, among some of the wealthiest of them, with an apparent loss of concern for development assistance does little to allay

such fears. No doubt there are new technologies which would permit the developing countries to by-pass the pollution stage and leapfrog into clean processing and clean power. No doubt the environmental risks inherent in building high dams and jumping into the middle of higher scientific monocultures can be offset by better environmental planning by growing cadres of technical expertise and wider scientific know-how. No doubt a decentralized plan for new towns and industries serving and stimulated by the Green Revolution offers a more desirable pattern than the likelihood of unrestricted, pell-mell urbanization in the next decades. No one denies that there can be better environmental answers. The difficulty is that many of them involve more capital, all of them require more skill, and none of them seems to be linked in any creative way with world strategies to permit developing countries to earn the needed capital or secure the extra skills. But at this point the issues go beyond the interdependence of nations in the planet's biosphere. The question turns on whether the technosphere—the constructed world order of technological innovation, investment flows, and commercial exchanges—can also be revised and managed to recognize the interdependence of nations and the underlying community of the species man.

14 COEXISTENCE IN THE TECHNOSPHERE

THE BLEAK MATHEMATICS OF population growth, of needed food supplies, of urban pressure, and of the capital sums required to mitigate their effects leave us in no doubt about the threat to humanity in developing lands. By the year 2000, their numbers will have grown by nearly three billion—or more than doubled in thirty years. To keep pace with this growth and to ensure a modest increase of income above the pitiful $100 a year of the great majority, governments must aim at economic growth of at least 6 per cent a year. To do this they must push up annual savings to well above 15 per cent a year of gross national product (the sum of goods and services), and do this in communities where, in many cases, 90 per cent of the people live little above margins of subsistence. Since much of the equipment, the technology, and the skills they need cannot yet be secured locally, parts of the needed investment must be in the shape of foreign exchange.

It is the considered view of every responsible international agency or commission that these targets are not attainable unless the developing nations have much greater access to developed markets and continue to receive a steady, and for a time increasing, flow of concessionary finance from the already wealthy lands.

The very respectable growth rates of the last decade were, as we have seen, to some extent secured by very large borrowing abroad. Today, the return flow of their payments to developed countries—of over $4 billion a year—is not much less than the concessionary finance made available by developed countries. This has stuck fast at about $6 billion and, in these times of increasingly inward-looking economic policies, shows little

sign of increasing. Nor is the present mood of industrialized lands inclined to compensate for lagging capital flows by wider opportunities for trade.

The concessions to the developing world's manufactured exports negotiated by the United Nations Trade and Development Organization (UNCTAD) do not amount to more than a billion dollars a year. But the World Bank estimates a needed increase in exports from $7 billion to $28 billion a year by 1980 if growth targets are to be met. And all these calculations were made before any extra sums were added for essential environmental expenditure.

Were we to take seriously just three essential elements in a better environment—the backing up of the Green Revolution by popular participation and technical expertise, the linking to it of policies for decentralized labor-intensive industry and regional city building, and, perhaps most urgent of all, world resources sufficient to improve diets and, in particular, make good the protein deficiency among the poor countries' children, we could safely add another $100 billion a year in immediately necessary investment and at least double the expert skills needed to invest it wisely.

This is still only half the planet's lamentable annual budget of $200 billion for arms, which absorbs not only resources but trained manpower and scarce scientific expertise as well. In any case, a large share of the needed investment would be provided by developing nations themselves —so far 75 to 80 per cent of all investment for development has been raised locally. But the additional capital supplementing existing flows of aid and backed by training programs for development action would bring governments in developed lands to within sight of the 1 per cent of gross national product first suggested as the target for assistance in 1964 and half promised and half forgotten ever since. It would also begin to provide, both in developed and developing lands, the expert cadres needed for more rapid advance.

But the plain truth is that, on present evidence, neither the extra funds nor the extra openings for training nor the wider markets for trade are likely to be forthcoming. Indeed, a shrinking of existing opportunities is even possible. The degradation of human conditions in developing lands which must follow upon too low a rate of economic growth and social transformation is therefore likely to deepen in the seventies and to grow to catastrophic proportions in the 1980s.

As with the developed nations at the end of their first thirty years of

rapid modernization—in the "hungry" 1840s—the obstructions seem to be outpacing the opportunities, the destruction of old ways appearing ahead of the creation of the new. It would be a bold prophet who, in such conditions, could look forward to anything but a deepening and spreading trend toward violence and anarchy in the wake of growing resentment and disappointed hope.

Yet during these same decades, there can be no doubt that the expectations of the developed peoples are likely to be centered on rising incomes and continued prosperity. If we carry on the curve of the 1950s and 1960s, we can easily forecast annual per capita incomes approaching $10,000 by the year 2000, and in the upper brackets, the two-home, three-car, four-TV-set family as the norm. Such standards could be the lot of a privileged elite of some one and a half billion developed peoples while for five billion others, an average income of $400 a year is the utmost reach of hope. And they, too, might be something of an elite while at the bottom of the social pyramid millions would be stunted by malnutrition and millions more scratching a bare living in filthy, workless cities and disintegrating countrysides. If developing peoples were as ignorant as Pharaoh's slaves of how "the other half" lives, they might toil on without protest. But the transistor and the satellites and world-wide TV have put an end to that kind of ignorance. Can we rationally suppose that they will accept a world "half slave, half free," half plunged in consumptive pleasures, half deprived of the bare decencies of life? Can we hope that the protest of the dispossessed will not erupt into local conflict and widening unrest?

Meanwhile, only a rough equilibrium of power, a precarious "balance of terror," underlies the relations of the world's great powers. It is only with difficulty that they can avoid being drawn into local conflicts and the more the conflicts erupt, the more their wisdom, diplomacy, and restraint may be taxed by the mounting pressures. Even today their fears are expressed in elaborate and still-proliferating weapon systems, in underground nuclear testing. Some powers, tragically, are still continuing to test in the air. These fears underlie the most dangerous of all pollutions, indiscriminate radiation, and could, if they escalate into a total confrontation, undermine all organized living and inflict grave, perhaps irreversible genetic damage on the few pitiful specimens who might survive the blast, the radiation, and the consequent visitations of world-wide famine and plague.

It is sometimes said of those who try to persuade man of his environ-

mental predicament that they paint a picture so gloomy and irreversible that the average citizen's response is to go out and buy a can of beer. If nothing can be done to escape the onward rush of some irresistible eco-doom, then why take the trouble even to return the can? But indeed over a vast range of environmental problems, action *is* possible, policies *are* available, reversals *can* take place, water run clean, the sun shine over clear cities, the oceans cleanse our human shores, and harvests ripen in uncontaminated fields.

Indeed, some nations and other jurisdictions already are launched on effective planning and pollution-control programs. Already some cities enjoy cleaner air than they knew three or four decades ago. Rivers are being cleaned up and fish are returning to them. There are places where rangelands are managed properly, where soil erosion has been stopped, wildlife is preserved and timberland carefully reforested. There are even examples of reversing the deterioration of inner cities. And all this has been done within the limits of existing knowledge, known techniques, and institutional capabilities. There is, in fact, only one place where fear and doom are truly appropriate and that is when we confront man's oldest habit and most terrible institution—the organized, systematic killing of his own kind.

15 STRATEGIES FOR SURVIVAL

The Need for Knowledge

BUT WE ARE NOT sleepwalkers or sheep. If men have not hitherto realized the extent of their planetary interdependence, it was in part at least because, in clear, precise physical and scientific fact, it did not yet exist. The new insights of our fundamental condition can also become the insights of our survival. We may be learning just in time.

There are three clear fields in which we can already begin to perceive the direction in which our planetary policies have to go. They match the three separate, powerful and divisive thrusts—of science, of markets, of nations—which have brought us, with such tremendous force, to our present predicament. And they point in the opposite direction—to a deeper and more widely shared knowledge of our environmental unity, to a new sense of partnership and sharing in our sovereign economics and politics, to a wider loyalty which transcends the traditional limited allegiance of tribes and peoples. There are already pointers to these necessities. We have now to make them the new drives and imperatives of our planetary existence.

We can begin with knowledge.

The first step toward devising a strategy for planet Earth is for the nations to accept a *collective* responsibility for discovering more—much more—about the natural system and how it is affected by man's activities and vice versa. This implies cooperative monitoring, research, and study on an unprecedented scale. It implies an intensive world-wide network for the systematic exchange of knowledge and experience. It implies a quite new readiness to take research wherever it is needed, with the backing of international financing. It means the fullest cooperation in

converting knowledge into action—whether it be placing research satellites in orbit or reaching agreements on fishing, or introducing a new control for snail-borne disease.

But it is important not to make so much of our state of ignorance that we are inhibited from vigorous action now. For while there is much that we do not yet understand, there are fundamental things that we *do* know. Above all, we know that there are limits to the burdens that the natural system and its components can bear, limits to the levels of toxic substances the human body can tolerate, limits to the amount of manipulation that man can exert upon natural balances without causing a breakdown in the system, limits to the psychic shock that men and societies can absorb from relentlessly accelerating social change—or social degradation. In many cases we cannot yet define these limits. But wherever the danger signals are appearing—inland seas losing oxygen, pesticides producing resistant strains of pests, laterite replacing tropical forests, carbon dioxide in the air, poisons in the ocean, the ills of the inner cities—we must be ready to set in motion the cooperative international efforts of directed research which make available, with all possible speed, solutions for those most intimately concerned with the immediate problem and wider knowledge for all men of how our natural systems actually work. To go blindly on, sharing, inadvertently, the risks and keeping to ourselves the knowledge needed for solutions can only mean more agonies than we can cope with and more danger than future generations deserve.

A full and open sharing of new knowledge about the interdependence of the planetary systems on which we all depend can also help us, as it were, to creep up on the infinitely sensitive issues of divisive economic and political sovereignty.

Sovereignty and Decision-Making

Given our millennial habits of separate decision-making and the recent tremendous explosion of *national* power, how can any perception of the biosphere's essential unity and interdependence be combined with the acutely self-conscious separate sovereignty of more than 130 national governments?

Yet, in fact, for at least a century, some habits of cooperation have been accepted by states simply through recognition of their own self-

interests. Ever since the world economy began to increase in extent and interdependence in the eighteenth and nineteenth centuries, sovereign states have shared some of their authority either by binding themselves to certain forms of cooperative behavior or by delegating limited power to other bodies. Despite rhetorical insistence on absolute sovereignty, governments have recognized in practice that this is impossible in some cases and inordinately foolish in many more. It is no use claiming the sovereign right not to deliver other people's letters if they use their sovereign right to refuse yours. The alternative to international allocation of radio frequencies would be chaos in world communications to the disadvantage and danger of all states. In brief, when governments are faced with such realities, they have exercised their inherent sovereign right to share voluntarily their sovereignty with others in limited and agreed areas of activity.

In the twentieth century, as a consequence of an ever greater overlap between supposedly sovereign national interests, the number of international treaties, conventions, organizations, consultative forums, and cooperative programs has multiplied rapidly. The growth of an intergovernmental community finds its most concrete expression in the United Nations and its family of specialized functional agencies and regional commissions. Outside the United Nations system, there has been an analagous growth of international organizations, governmental and non-governmental, especially on the regional level.

All intergovernmental institutions are still, ultimately, creatures of national governments, but a large amount of their day-to-day work is sufficiently and obviously useful that a measure of authority and initiative comes to rest with them. They acquire support within national governments from the relevant ministries and agencies which, in turn, find useful constituencies within the ranks of international organizations. This is, none of it, a formal departure from sovereignty. But a strict, literal definition of sovereignty gets blurred in practice and the existence of continuous forums for debate and bargaining helps instill the habit of cooperation into the affairs of reluctant governments.

It is on to this scene of ultimate national sovereignty and proliferating intermediate institutions that the new environmental imperatives have broken in the last few years. The first effect has undoubtedly been to complicate still further a very complicated situation. Quite suddenly, for a whole variety of reasons, a very wide range of institutions have added

an environmental concern to their other interests. In some cases, traditional programs and activities have been renamed to qualify them under the environmental rubric. In others a number of agencies have taken up the same environmental topic, though mainly from differing points of view. There has been some genuine innovation, and there is much ferment and groping as international organizations, to a greater or lesser degree, seek to comprehend and to adapt to the environmental imperative.

One example of combined good will and overlap can be taken from air pollution. The industrialized nations are the main polluters. So regional groupings are starting to respond. The Organization for Economic Cooperation and Development—the successor to the old Marshall Plan bureaucracy, linking North America with Western Europe and, more recently, Japan—is setting up an Environment Committee to coordinate a number of its existing research activities, for instance, its Air Management Research Group. The regional commissions of the United Nations are also beginning to move and the Economic Commission for Europe also has a Committee of Experts on Air Pollution. So has the North Atlantic Treaty Organization, which includes air pollution among a number of other research activities such as open waters and inland waters pollution, disaster relief, and regional decision-making for environmental issues.

This picture of somewhat uncoordinated and hence not fully focused activity, however, largely reflects the recentness of the environmental awareness. National governments, too, are trying to find means of adding an environmental angle of vision to institutions which have hitherto followed the traditional one-track approach to specialized problems through separate and usually uncoordinated administration. A rash of environmental councils and commissions is now appearing round the world to coordinate the activities of hitherto separate ministries. Several countries have taken the bolder step of bringing relevant ministries—housing, transport, technology—together in single Departments of the Environment. The various experiments are mostly not yet two years old, and it is too soon to say how well they may succeed in introducing an integrative view of man-environment relations into the national decision-making processes. Certainly it will not be easy.

And certainly it will be still more difficult at the international than

at national levels of decision-making. So locked are we within our tribal units, so possessive over national rights, so suspicious of any extension of international authority that we may fail to sense the need for dedicated and committed action over the whole field of planetary necessities. Nonetheless there are jobs to be done which perhaps require at this stage no more than a limited, special, and basically self-interested application of the global point of view. For instance, it is only by forthright cooperation and action at the global level that nations can protect mankind from inadvertent and potentially disastrous modification in the planetary weather system, over which no nation can assert sovereignty. Again, no sovereignty can hold sway over the single, interconnected global ocean system which is nature's ultimate sink and man's favorite sewer.

Where pretentions to national sovereignty have no relevance to perceived problems, nations have no choice but to follow the course of common policy and coordinated action. In three vital, related areas this is now the undeniable case—the global atmosphere, the global oceans, and the global weather system. All require the adoption of a planetary approach by the leaders of nations, no matter how parochial their point of view toward matters that lie within national jurisdiction. A strategy for planet Earth, undergirded by a sense of collective responsibility to discover more about man-environment relations, could well move, then, into operation on these three fronts: atmosphere, oceans, and climate. It is no small undertaking, but quite possibly the very minimum required in defense of the future of the human race.

But it is not only the pollutions and degradations of the atmosphere and the oceans that threaten the quality of life at the planetary level. There are threats, too, of disease spreading among undernourished children, of protein deficiency maiming the intelligence of millions, of spreading illiteracy combined with rising numbers of unemployed intellectuals, of landless workers streaming to the squalid cities, and worklessness growing there to engulf a quarter of the working force. An acceptable strategy for planet Earth must, then, explicitly take account of the fact that the natural resource most threatened with pollution, most exposed to degradation, most liable to irreversible damage is not this or that species, not this or that plant or biome or habitat, not even the free airs or the great oceans. It is man himself.

Here again, no one nation, not even groups of nations, can, acting separately, avoid the tragedy of increasing divisions between wealthy north and poverty-stricken south in our planet. No nations, on their own, can offset the risk of deepening disorder. No nations, acting singly or only with their own kind, rich or poor, can stave off the risk of unacceptable paternalism on the one hand or resentful rejection on the other. International policies are, in fact, within sight of the point reached by *internal* development in the mid-nineteenth century. Either they will move on to a community based upon a more systematic sharing of wealth —through progressive income tax, through general policies for education, shelter, health, and housing—or they will break down in revolt and anarchy. Many of today's proposals for development aid, through international channels, are a first sketch of such a system.

But at this point, if gloom is the psychological risk of all too many ecological forecasts, may we not go to the opposite extreme of Pollyanna optimism in forecasting any such growth of a sense of community in our troubled and divided planet? With war as mankind's oldest habit and divided sovereignty as his most treasured inheritance, where are the energies, the psychic force, the profound commitment needed for a wider loyalty?

Loyalty may, however, be the key. It is the view of many modern psychologists that man is a killer not because of any biological imperative but because of his capacity for misplaced loyalty. He will do in the name of a wider allegiance what he would shrink to do in his own nature. His massive, organized killings—the kind that distinguishes him from all other animals—are invariably done in the name of faith or ideology, of people or clan. Here, it is not wholly irrational to hope that the full realization of planetary interdependence—in biosphere and technosphere alike—may begin to affect man in the depths of his capacity for psychic commitment. All loyalty is based on two elements—the hope of protection and the hope of enhancement. On either count, the new ecological imperative can give a new vision of where man belongs in his final security and his final sense of dignity and identity.

At the most down-to-earth level of self-interest, it is the realization of the planet's totally continuous and interdependent systems of air, land,

and water that helps to keep a check on the ultimate lunacies of nuclear weaponry. When after the nuclear testing conducted in 1969, the air above Britain was found to contain 20 per cent more strontium 90 and cesium 137, it is not a very sophisticated guess that the air of the testing states contained no less. It is the force of such recognitions that lay behind the first global environmental agreement—the Test-Ban Treaty negotiated in 1963—which has kept earlier nuclear powers out of competitive air testing and saved unnumbered children from leukemia. Similar calculations of enlightened self-interest underlie the treaty to keep nuclear weapons out of space, off the seabeds, and away from Antarctica.

Where negotiations continue—as in the Treaty to prevent the spread of nuclear weapons, or the Soviet-American talks on a mutual limitation of strategic arms—the underlying rationale is still the same. As the airs and oceans flow round our little planet, there is not much difference between your strontium 90 and my strontium 90. They are lethal to us both.

It is even possible that recognition of our environmental interdependence can do more than save us, negatively, from the final folly of war. It could, positively, give us that sense of community, of belonging and living together, without which no human society can be built up, survive, and prosper. Our links of blood and history, our sense of shared culture and achievement, our traditions, our faiths are all precious and enrich the world with the variety of scale and function required for every vital ecosystem. But we have lacked a wider rationale of unity. Our prophets have sought it. Our poets have dreamed of it. But it is only in our own day that astronomers, physicists, geologists, chemists, biologists, anthropologists, ethnologists, and archaeologists have all combined in a single witness of advanced science to tell us that, in every alphabet of our being, we do indeed belong to a single system, powered by a single energy, manifesting a fundamental unity under all its variations, depending for its survival on the balance and health of the total system.

If this vision of unity—which is not a vision only but a hard and inescapable scientific fact—can become part of the common insight of all the inhabitants of planet Earth, then we may find that, beyond all our inevitable pluralisms, we can achieve just enough unity of purpose to build a human world.

In such a world, the practices and institutions with which we are familiar inside our domestic societies would become, suitably modified,

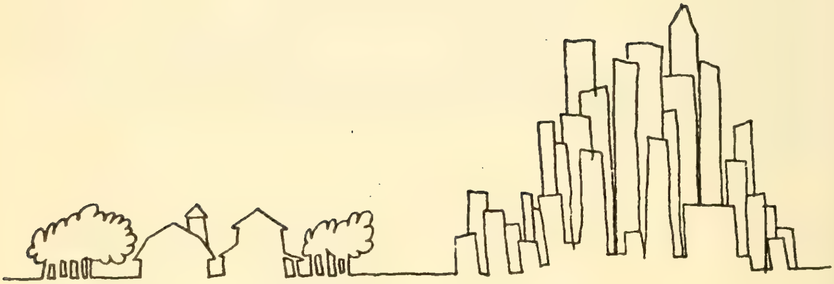
the basis of planetary order. In fact, in many of our present international institutions the sketch of such a system already exists. A part of the process would be the nonviolent settlement of disputes with legal, arbitral, and policing prodecures on an international basis. Part of it would be the transfer of resources from rich to poor through progressive world sharing—the system of which a 1 per cent standard of gross national product for aid-giving is the first faint sign. World plans for health and education, world investment in progressive farming, a world strategy for better cities, world action for pollution control and an enhanced environment would simply be seen as logical extensions of the practice of limited intergovernmental cooperation, already imposed by mutual functional needs and interests.

Our new knowledge of our planetary interdependence demands that the functions are now seen to be world-wide and supported with as rational a concept of self-interest. Governments have already paid lip service to such a view of the world by setting up a whole variety of United Nations agencies whose duty it is to elaborate world-wide strategies. But the idea of authority and energy and resources to support their policies seems strange, visionary, and Utopian at present, simply because world institutions are not backed by any sense of planetary community and commitment. Indeed, the whole idea of operating effectively at the world level still seems in some way peculiar and unlikely. The planet is not yet a center of rational loyalty for all mankind.

But possibly it is precisely this shift of loyalty that a profound and deepening sense of our shared and interdependent biosphere can stir to life in us. That men can experience such transformations is not in doubt. From family to clan, from clan to nation, from nation to federation—such enlargements of allegiance have occurred without wiping out the earlier loves. Today, in human society, we can perhaps hope to survive in all our prized diversity provided we can achieve an ultimate loyalty to our single, beautiful, and vulnerable planet Earth.

Alone in space, alone in its life-supporting systems, powered by inconceivable energies, mediating them to us through the most delicate adjustments, wayward, unlikely, unpredictable, but nourishing, enlivening, and enriching in the largest degree—is this not a precious home for all of us earthlings? Is it not worth our love? Does it not deserve all the inventiveness and courage and generosity of which we are capable to preserve it from degradation and destruction and, by doing so, to secure our own survival?

Report on National Growth 1972



To the Congress of the United States:

I am pleased to transmit the first biennial Report on National Growth as required by section 703(a) of the Housing and Urban Development Act of 1970.

This report was developed by the members and staff of the Domestic Council Committee on National Growth, under the Chairmanship of George Romney, Secretary of Housing and Urban Development. Their efforts are deeply appreciated.

Richard Nixon

THE WHITE HOUSE.
FEBRUARY 1972.

INTRODUCTION

The desirability of establishing a national growth policy for the United States has long been a subject for serious study and debate. Over the years, contributions to this discussion from the academic community and from private enterprise have been numerous and significant. Earlier in this Administration, a White House report, "Toward Balanced Growth, Quantity With Quality," spotlighted a wide variety of issues concerning the quest for better growth and development. The debate over national growth policy culminated in 1970 with the passage of title VII of the Housing and Urban Development Act. This act requires that, "In order to assist in the development of a national urban growth policy, the President shall utilize the capacity of his office * * * and of the departments and agencies within the executive branch to collect, analyze, and evaluate such statistics, data, and other information (including demographic, economic, social, land use, environmental, and governmental information) as will enable him to transmit to the Congress during the month of February in every even-numbered year beginning with 1972, a Report on Urban Growth. * * *"

This report has been prepared in response to that act. The statutory findings and the overall objectives which led to that requirement suggest, however, that the term "national urban growth policy" is too narrow. Instead, this report will use the term "national growth policy," recognizing that rural and urban community development are inseparably linked. It is important to realize that urban growth problems cannot be discussed in a useful and intelligent manner without discussing rural growth as well. And it is also important to note that citizens residing in our rural areas are confronted with problems no less pressing and no less deserving of national attention than those of our citizens who are afflicted by what is generally described as "the urban crisis."

Another important point of clarification concerns the central purpose of this report. Its aim, as the statute puts it, is to "assist in the development" of national policy—not to "enunciate" such

policy. This document makes no claim, therefore, to present a single, comprehensive national growth policy for the United States. It does not presume to reveal some master plan for directing the multitude of public and private decisions that determine the patterns of progress in modern America. It represents one element in our search for an adequate growth strategy; in no sense does it represent the end of that search.

The longstanding issues concerning the growth of our Nation are much too complex to be resolved in any dogmatic fashion. There are honest and legitimate differences among our people as to how and where such issues should be treated. To the extent that any single philosophy of national growth emerges from this report, it is a philosophy which is based on a respect for diversity and pluralism.

The task of formulating a growth policy which is more than mere rhetoric, a policy that really makes a difference in our national life, is an extremely difficult one. Its difficulty is compounded because the term "national growth policy"—and even the term "urban growth policy"—has come to embrace virtually everything we do—privately and publicly—that shapes the future of our society. As a result, a "national growth policy" is often viewed as a panacea for all our social ills.

Indeed, when the Congress set forth in section 702(d) of the Housing and Urban Development Act of 1970 eight recommended components of a national growth policy, it described them in terms so broad as to encompass the whole body of our domestic concerns. Numerous other problems have been identified as potential targets for a national growth policy, including such general conditions as the destruction of the environment, the inefficient use of resources, inequality in the treatment of various social groups, the inadequate or improper financing of public activities, and inadequate institutional structures for public decisionmaking.

The hard, unavoidable fact of the matter, however, is that no single policy, nor even a single coordinated set of policies, can remedy or even significantly ameliorate all of our ills. As our problems are many and varied and changing, so our solutions must be multiple and diversified and flexible.

An effective and realistic approach to national growth must also take account of the rich variety of cultures which make

up our country—and of our heritage of freedom in choosing among various styles of life. One important source of our strength as a people has been our unwillingness to trust our destiny to the edicts of any government or the whims of any group. There is no place in our country for any policy which arbitrarily dictates where and how our citizens will live and work and spend their leisure time. Our plans for national growth must rather seek to help individual Americans develop their unique potentials and achieve their personal goals.

All of these considerations should not be seen as precluding a new general strategy for national development. We need such a strategy; we must develop a clear and coherent approach. But as we do so, let us remember that this task is not "the work of a day." Rather it must be the work of a generation. It is not something that can be done according to neat blueprints drawn up in advance of action. Rather it must grow out of an ongoing process in which we learn by doing and in which we are always ready to learn something new.

This first biennial report on national growth marks the beginning of a systematic effort to

I. Understand the forces that are shaping the communities in which we live and work;

II. Articulate some of the challenges that must be confronted as the Nation responds to the challenges of growth;

III. Identify recent developments at the State and local level for coping more effectively with growth;

IV. Identify major actions of the Federal Government undertaken to deal with the problems of growth; and

V. Advance recommendations for Federal action to strengthen the Nation's ability to deal with the challenges of growth more effectively.

Each of these five objectives are addressed in a separate chapter of this report.

Recognizing that virtually any item on the Nation's domestic agenda could be construed as a proper subject for this report, the report nevertheless tries to focus on a few critical concerns. It is concerned primarily with the twin objectives of balanced and orderly growth. Meeting these objectives will require stimulating and channeling private initiative, since progress in this field may depend more on how ongoing investment is directed

than on generating vast new expenditures. It will also require strengthening the capacity of government at all levels to respond to growth challenges. Many of this Administration's most important initiatives have been devoted to the achievement of this goal. For it is the conviction of this Administration that public policies for balanced and orderly growth will be no more effective than the mechanisms through which they are shaped and carried out.

CHAPTER II

THE CHALLENGE OF BALANCED AND ORDERLY GROWTH

The growth and change that our Nation has experienced in the past have brought substantial benefits. Population growth has been accompanied by even more rapid economic expansion, enabling the United States to enjoy the highest standard of living ever achieved by a major nation. Generally, the patterns of migration from rural to urban areas and from one region of the country to another have brought population to where employment opportunities are. Urban development and suburban growth have given millions of American families better housing, facilities, and services. The automobile and the extensive highway system—probably the most important forces influencing the pattern of growth in the post-World War II period—have increased the mobility of American families and provided them with greater access to jobs, housing, recreation, and shopping. This growth, in the form of population changes, technological development, economic expansion, and individual initiative, will almost certainly continue during the foreseeable future.

PROBLEMS ASSOCIATED WITH GROWTH

In the last decade, however, we have begun to recognize that a number of problems are associated with the process and patterns of growth.

Policies are needed to deal with these problems and to insure that future growth is both orderly and balanced. As President Nixon has said, "the growth which this Nation will inevitably experience in the coming decades will be healthy growth only if it is balanced growth—and this means growth which is distributed among both urban and rural areas." Orderly growth

requires overcoming the problems associated with past growth and preventing their repetition in the future. This will necessitate action by all parts of our society—individuals and families, private enterprise, and government at the local, State, and Federal levels.

The Decline of Rural Areas and Small Towns

The Nation's total rural population—that is, the number of persons living in open country or in places with less than 2,500 inhabitants—has remained relatively constant over most of this century. Nevertheless, changes in population composition and economic activity have produced a number of serious problems for many small, nonmetropolitan towns and other rural areas.

Since the 1940's, farm population has declined so rapidly that it now constitutes less than one-fifth of total rural population. At the same time, the number of market and service centers needed by this shrinking segment of rural America has fallen, meaning that many small towns are no longer able to serve their original function.

While some growth in nonfarm employment did occur in nonmetropolitan areas during the decade of the 1960's, the increase was unevenly distributed. In fact, half of the Nation's counties did not experience any growth in nonfarm employment, due to such factors as their remoteness from large-volume markets, lack of natural resources and skilled labor, inadequate public facilities, absence of recreational and cultural activities, the financial difficulties of local governments, and limited pools from which to draw effective leadership.

Where employment opportunities have failed consistently to match the number of jobseekers, many younger and better educated persons have sought jobs in larger towns and cities, leaving behind an older and less skilled population in the midst of deteriorating economies. Often, the result is a tax base inadequate to finance basic public services or to attract new job-producing investment (which would augment the tax base).

Consequently, many indicators show nonmetropolitan areas lagging behind metropolitan areas in terms of economic and social conditions. For example, in 1970, 13.8 percent of nonmetropolitan families were below the official poverty level compared with 7.9 percent of metropolitan families; and the median income of families in nonmetropolitan areas was $2,000 less than that of

families in metropolitan areas. The percentage of high school and college graduates in the rural population is smaller. Rural areas have fewer medical and dental personnel in proportion to their population. The incidence of substandard housing is about three times higher in nonmetropolitan areas (where three-fifths of the Nation's substandard housing units were located in 1970). And in many rural areas, vital public services and facilities—such as police and fire protection, a clean water supply, sewage disposal, air transportation facilities, and recreational and cultural opportunities—are unavailable, inadequate, or provided only at high cost.

The Changing Role of the Central City

Shifts in population and changes in the location of economic activity have also had a substantial impact on the physical, social, and economic vitality of many central cities.

The influx of low-income families and individuals has placed a heavy burden on municipal services and facilities. At the same time, the revenue sources available to pay for them have been shrinking, as middle and upper income families, together with commercial and industrial enterprises, move to the suburbs. These families may continue to place demands on central city facilities and services, intensifying the problems cities face in providing them.

The stagnant or declining tax bases of most large cities, together with the growing costs of the police, fire, welfare, and sanitation services, have often led to a reduction in the quality of services. This falls especially hard on poor families since they suffer the consequences of crime, vandalism, drug addiction, and neighborhood deterioration more than other Americans.

Racial and Economic Concentration

Population movements have increased racial and economic concentration in urban areas. The percent of metropolitan families with incomes below the official poverty level living in the central city increased from 61.3 in 1960 to 63.1 in 1970. Between 1960 and 1970, the percent of blacks living inside central cities increased from 51.5 to 55.2 and the percent of whites living outside central cities increased from 32.6 to 38.6. A large number

of urban poor, black, and other minority families are concentrated in particular inner city neighborhoods.

Environmental and Transportation Effects

Increasing population in large metropolitan areas has intensified problems of air, water, and noise pollution and other forms of environmental degradation. Forests, streams, swamps, shorelines, wetlands, open space, and scenic areas have been consumed by metropolitan development.

Few cities have found ways to control traffic congestion. Many urban dwellers spend a substantial proportion of their time contending with problems of clogged streets and highways and trying to find parking spaces at their destination. At the same time, declining densities within metropolitan areas have made it difficult to provide efficient, self-supporting public transportation service.

Rising Land Costs

In most areas of the United States, rapid increases in land costs have accompanied urban growth. Census Bureau surveys of the price of new homes indicate that land values increased about 6 percent annually between 1963 and 1969. The National Association of Homebuilders report that the proportion of a new home's value accounted for by site costs rose from 11 percent in 1949 to 24 percent in 1969. Similarly, site costs of homes financed with FHA-insured loans rose from 17 percent of total value in 1960 to 20 percent in 1970. Inflation in land prices contributed to the 75-percent increase in housing costs during the 1965–70 period.

FORMULATION OF A SINGLE COMPREHENSIVE NATIONAL GROWTH POLICY: OBSTACLES AND ISSUES

Each of the problems discussed above is a primary concern of this Nation. Government should address itself to alleviating these problems, and, at the same time, adopting policies toward growth that will prevent their recurrence in the future.

Developing a single comprehensive strategy—a national growth policy—for dealing with the forces of growth, is an extremely difficult undertaking. It is made so by a variety of obstacles and issues that must be clearly recognized if our Nation is

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to be successful in meeting the challenge of growth. This section discusses some of these obstacles and issues.

Specifying the Goals and Problems of Growth

Defining the objectives of a national growth policy requires a searching consideration of our national objectives and priorities. This task becomes increasingly difficult as we move closer to specific goals.

In the abstract, the concept of growth policy commands nearly universal support. Conflicts and issues arise, however, as individual issues are specified and priorities established. A recent unpublished study of growth policy issues cites 25 domestic problems which have been identified as possible targets of a national growth policy. It observes, however, that few individuals and groups see the growth question this broadly. Most individuals look to a growth policy to remedy the four or five problems about which he or she is most concerned. To the extent these problems conflict with one another, developing a comprehensive growth policy becomes more difficult. In fact, solving even one of these problems may *create* new problems for which various groups will look to a growth policy for solution.

Not only do individuals frequently disagree over which problems in the growth area are most pressing; many times individuals disagree over whether a particular consequence of growth is indeed a problem at all. The well-known phenomenon of "sprawl" provides a good example.

As chapter I points out, population densities in urban areas have been falling for some time. The resulting living patterns have been attacked by some individuals as wasteful and inefficient. Low-density utilization of land use raises the costs of public facilities—requiring extra miles of streets and sewer lines—and increases the distance traveled in reaching destinations. It is sometimes argued that self-contained villages in which, for example, workers walk to work would be less expensive than present patterns.

But it is well to place this trend in proper perspective. Low-density living appears to be the style of living most preferred by our population. Many individuals and families, hence, are willing to pay the price of sprawl—greater distances traveled (although not necessarily more time spent traveling), higher public facility costs—in order to enjoy low-density living.

Identifying the Link Between the Growth Process and Growth Problems

The problems associated with growth, by any definition, include many of the most intractable social and governmental concerns of this country. The relationship of these issues to national growth is complex and sometimes obscure. Growth is rarely the single cause of a problem; more often, a problem or condition both affects the patterns of growth and is affected by them. Racial and economic discrimination, for example, has been a cause of unbalanced growth, while growth, in turn, has contributed to the problem.

Influencing the Many Determinants of Growth

Patterns of growth are influenced by countless decisions made by individuals, families, and businesses. These decisions are aimed at achieving the personal goals of those who make them, and reflect healthy free choices in our society. Locational shifts by individuals reflect, in part, a search for better job opportunities or for a better climate, while businessmen relocate where they can operate most efficiently and therefore make the most profit.

The factors that influence these decisions may be susceptible to changes that will alter the emerging growth patterns, but, in a Nation that values freedom in the private sector and democratic choice in the public, the decisions themselves cannot be dictated.

Determining the Proper Level of Government To Influence Growth

In many nations, the central government has undertaken forceful, comprehensive policies to control the process of growth. Similar policies have not been adopted in the United States for several reasons. Among the most important of these is the distinctive form of government which we value so highly in this country. Ours is a *federal* system, with powers shared between the States and National Government. This system preserves the ability of citizens to have a major voice in determining policies that most directly affect them. This voice is sustained by keeping government close to the people.

Another important reason for the lack of a single dominant growth policy is the sheer size of our Nation. The United States is a *vast* country—many times bigger than even the largest of the

Western European countries. While we may observe certain common patterns of growth throughout the Nation, there are also distinct differences within each area. Patterns of growth reflect many determinations having primarily local significance, such as local tax levies; the location of public facilities and roads; the extension of sewer, water, electric, and gas services; specific zoning and building regulations; the approval of development plans. These decisions can best reflect specific community factors and objectives if they are made at the local level. Accordingly, it is not feasible for the highest level of government to design policies for development that can operate successfully in all parts of the Nation.

MEETING THE CHALLENGES OF GROWTH

If we are to meet the challenges of national growth, we must begin by determining where in our governmental system we can best deal with the problems and opportunities of growth.

In some cases, the Federal Government is the only body with the capability to assure balanced and orderly growth. This is especially true in the economic area. Fiscal and monetary policy, prudently conducted, can do much to keep the Nation's economy growing at its full potential. Similarly, Federal support for research and development can help accelerate the pace of technological advancement, which is so necessary to a growing economy.

There are also some growth problems which are truly national problems, and which should be addressed by the Federal Government. These problems are national, not in the sense that they crop up in many places—street lighting is a pervasive problem but hardly a national problem—but because no one State can deal with them effectively. Water and air pollution are good examples of these national problems.

However, any consideration of growth issues must recognize that many of these issues fall within the boundaries of State and local governments. The following chapter looks at the way in which these bodies have responded to the forces of growth in recent years.

CHAPTER IV

ADMINISTRATION ACTIONS TO DEAL WITH THE CHALLENGES OF GROWTH

PAST FEDERAL INVOLVEMENT

Federal policies have significantly shaped our Nation's development throughout its history—sometimes intentionally, sometimes inadvertently. During the 19th century, the Federal Government actively encouraged population settlement in the vast, and largely uninhabited interior sections of the country. Land grants under the Homestead Act provided incentives for private citizens to locate in the new territories. At the same time, Federal aid to the fledgling railroad industry linked developed and undeveloped parts of the country, facilitating the economic growth of the new settlements. Federal immigration policy permitted large numbers of new citizens to come to our shores in the years prior to World War I, contributing significantly to the rapid growth and development of the Nation.

Other actions by the Federal Government, though less dramatic, also had a major impact on the growth of particular areas. Such actions included the location of Federal installations, the placement of Federal contracts, and the development of an early highway network.

Beginning in the 1930's, there was a general expansion of Federal involvement in domestic affairs. This led to a number of new Federal initiatives affecting growth and development:

- The National Resources Board and its two successors represented a unique attempt at national planning before the effort was terminated in 1943.
- The Resettlement Administration, under authority of the National Industrial Recovery Act, initiated a wide range of housing and resettlement projects across the country.
- The Tennessee Valley Authority was designed in part to accelerate the economic development of an entire region.

• Federal assistance was authorized for home financing and low-rent public housing.

During the postwar era two historic pieces of legislation were enacted that addressed the two basic factors which underlie growth: national economic development and orderly community development. The Full Employment Act of 1946 established the national goal of full employment for the Nation's work force. The Housing Act of 1949 established the national goal of "a decent home in a suitable living environment for every American family."

In the 1950's under President Eisenhower, a massive program of Federal assistance to highways was initiated, opening up vast suburban areas for the construction of new housing. In the central cities, the Urban Renewal program was relied on to change land use patterns.

More recently, the Federal Government's reaction to problems associated with national growth has taken the form of hundreds of new, but narrow purpose, grant programs.

ADMINISTRATIVE AND PROGRAM INITIATIVES

Efforts to deal more effectively with the challenges of national growth were begun by this Administration immediately upon taking office.

On January 23, 1969, as one of the first official acts of his Administration, the President established an Urban Affairs Council to advise and assist "in the development of a national urban policy, having regard both to immediate and to long-range concerns, and to priorities among them."

Later, a Rural Affairs Council was established to assist the President in the development of policies for rural areas, and to assure that the interrelationships between rural and urban problems are taken into account in designing Federal programs.

These Councils, and later the President's Advisory Committee on Executive Organization, the Domestic Council, and the Office of Management and Budget, have vigorously addressed themselves to the task of making government work better in dealing with the challenges of growth. The product of these concerted efforts has been a set of forceful policies designed to:

1. Strengthen the capacity of State and local governments, to solve the problems that past growth has brought, and

to take advantage of the opportunities that future growth will bring;

2. Recast the structure of the Federal Government to make it more effective in assisting State and local governments carry out their responsibilities; and
3. Improve Federal approaches to growth problems where national interests are at stake.

Underlying each of these policies is the need to make Federal programs more responsive to the people and their locally elected officials, both in terms of the goals they seek to achieve and the way they deliver Federal assistance. This is an extremely important feature of the President's policy toward growth.

Where the Administration has been able to move ahead with its policies toward national growth under existing law, it has done so. Where new authority is needed to implement its policies, the Administration has taken the lead in drafting and working for passage of appropriate legislation.

This chapter describes Administration actions undertaken to date to promote more balanced and orderly growth. The following chapter makes recommendations for additional legislation which is needed to strengthen our ability as a Nation to meet the challenges of growth.

Strengthening the Federal System

The Administration has acted to facilitate delivery of Federal services and to improve communications among State, local, and Federal officials. These include:

- *Decentralization of decisionmaking authority* in numerous Federal grant programs to bring administration of these programs closer to the people they serve.
- *Reduction of redtape and processing time* within the Federal categorical grant system, through a rationalization of consistency procedures, joint funding simplification, intergovernmental cooperation, grant consolidation, and generally improved coordination.
- *Establishment of uniform regional boundaries* for Federal domestic agencies and increasing emphasis on Federal Regional Councils.

- *Establishment of the Environmental Protection Agency to* consolidate various Federal programs for protecting the environment.

Rural Development

The Administration has taken a number of steps to improve our rural development programs and has substantially increased program funding. For example, the funding of principal rural development programs in the Department of Agriculture this year—$2.8 billion—is more than four times that of fiscal year 1961 and twice that of fiscal year 1969. All told, 29 of the 34 rural development programs in that Department have been expanded since 1969.

In addition, the Department of Housing and Urban Development has nearly tripled its grants for nonmetropolitan planning districts since 1969. In the last fiscal year, 155 districts received $3.4 million in grants. Rural housing assistance, with an emphasis on low- and moderate-income families, has reached a record level of $1.6 billion under the Farmers Home Administration program—more than triple the 1969 level.

Transportation

Improved urban transportation is an important contributing factor to an evolving national growth policy. During the past 2 years, expanded programs with environmental safeguards have been initiated to improve urban transportation. By enacting the Urban Mass Transportation Assistance Act of 1970, Congress supported the Administration's proposal to provide substantial Federal funds in support of mass transportation—$3.1 billion for the first 5 years of the program. Between 1971 and 1973, the Urban Mass Transportation Administration will have committed over $2 billion for mass transit, including almost $1.7 billion for capital improvements.

The Federal-Aid Highway Act of 1970 also authorized new programs to meet the need for balanced transportation in urban areas, including fringe and corridor parking, airport and waterport access, and a Federal-aid urban system.

The urban system involves local officials, in cooperation with State highway departments, in the designation of arterials for Federal aid. This program provides a special source of funds for

improving a large number of major roadways and allows greater flexibility in the use of highway programs to provide for balanced transportation.

Another important feature of the 1970 legislation is the Urban Highway Public Transit Program, which permits the States to increase the efficiency of highways in transporting people rather than cars. Projects now underway include the exclusive bus lane on the Shirley Highway in northern Virginia, and similar projects in Los Angeles, northern New Jersey, Seattle, Milwaukee, Boston, and San Juan, P.R.

National Environmental Policy Act Implementation

The Administration has implemented the National Environmental Policy Act to assure that the growth implications of potential Federal and federally assisted activities are taken into account before final decisions on them are made. Section 102 (2) (C) of the act requires that Federal agencies issue for public comment detailed statements analyzing the environmental impact of proposed actions. Under guidelines set by the President's Council on Environmental Quality, agencies are required to assess the primary and secondary effects of a proposed action—such as a new highway, airport, or dam—on an area's environment and growth patterns. This process has enhanced citizens' capacity to play a constructive role in the debate over growth policy.

Use of Federal Land

An important part of national growth policy will involve future decisions on the use of federally owned land—both traditional "public domain" land and acquired property that becomes surplus. Congress is now considering recommendations by the Public Land Law Review Commission to permit public lands to be more effectively used for future growth. This Administration has also proposed legislation that will make it easier to transfer surplus Federal lands for use as new communities. The Property Review Board, established by President Nixon, is overseeing a review of the Government's holdings by Federal agencies to identify unneeded property, and is seeking to insure that Federal property is used as effectively as possible.

Housing

This Administration has sought to increase the housing opportunities of all Americans. Housing production and assistance, especially for low- and moderate-income families, has been greatly expanded over the past 3 years to the highest levels in our history. In 1971, total housing starts neared 2.1 million units, almost 25 percent of which were for low- and moderate-income families under Federal housing programs providing direct financial assistance. Programs and policies also have been implemented by the Department of Housing and Urban Development and the National Bureau of Standards to encourage the more efficient production of housing throughout the country. Toward this objective, these agencies have worked closely with the States through the National Conference of States on Building Codes and Standards.

Racial barriers have prevented minority groups from their full share of the benefits from national growth. The Presidential statement on equal housing opportunity of June 11, 1971, committed the Federal Government to work with State and local governments in expanding the freedom and the opportunity for all Americans to obtain adequate housing regardless of race.

New Community Assistance

As of December 31, 1971, the Federal New Communities program had agreed to help private developers undertake the development of seven new population centers, with several more under consideration. These centers will serve the objective of orderly growth within metropolitan areas by offering the promise of innovative, well-planned development and an attractive living and working environment. It is expected that these new centers will set a standard of excellence in planning, conservation, housing balance, education, health, and community participation.

All of the approved projects have strong programs for equal opportunity in housing and employment, and will contain a substantial amount of housing for persons of low and moderate income.

Planning Requirements

Many Federal programs require planning at the State, areawide, and local levels as a prerequisite for Federal grants.

At present, efforts are being made within the executive branch to improve and integrate planning requirements among Federal agencies. For example, within the last year the Environmental Protection Agency and the Department of Housing and Urban Development have agreed to integrate their water and waste management planning requirements. These agencies are now engaged in efforts to develop unified water and waste management planning requirements with the Economic Development Administration and the Farmers Home Administration.

The Department of Transportation presently has metropolitan-based pilot projects underway in each of the 10 Federal regions to integrate highway, airport, and mass transportation planning.

A–95 Reviews

One of the principal means for States and local governments to control development within their borders is through Office of Management and Budget Circular A–95, first issued by this Administration. This circular provides an opportunity for States and areawide agencies to review and comment on projects proposed for funding under a variety of Federal programs. In this way, it provides State and local governments with a potentially powerful instrument for coordinating growth.

Federal Property Insurance Programs

Urban crime, the riots of the 1960's, and the migration of many middle-income families out of the central city have forced many central city businesses—especially small businesses—to relocate. The exodus of such businesses and the resulting erosion of property tax bases have been key factors in the decline of central cities.

In inner city areas, basic crime and riot insurance protection often is not available. Since lending institutions require borrowers to have basic property insurance, existing businesses have found it difficult to obtain financing for modernization while new businesses have had difficulty obtaining startup funds.

In order to improve property insurance protection for central city businesses and homeowners, the Federal Insurance Administration has implemented two property insurance programs authorized by the Urban Property Protection and Reinsurance Act of 1968, as amended in 1970:

Under the first program, riot reinsurance protection is provided to primary insurers that cooperate in State FAIR plans (Fair Access to Insurance Requirements). These plans are designed to give urban residents and property owners in 26 States, the District of Columbia, and Puerto Rico access to basic fire, extended coverage, and vandalism and malicious mischief insurance.

Under the second program, which became effective on August 1, 1971, the FIA provides direct crime insurance policies at affordable rates covering losses from burglary, robbery, and theft (with appropriate deductible provisions and requirements for reasonable protective and loss-preventive measures and devices) in nine States and the District of Columbia.

More than $20 billion of basic property insurance has been provided to over 1 million urban area residents and property owners through FAIR plans. The new crime insurance program has already provided more than 2,000 direct crime insurance policies.

Planned Variations

On July 29, 1971, 20 existing model cities were selected to participate in a planned variation demonstration designed to test some of the concepts of urban community development revenue sharing. Of the 20 cities selected for this demonstration, 16 are receiving additional funds to implement a citywide Model Cities program with only the minimum Federal control required by statute and with a procedure to enable the local chief executive to coordinate Federal resources available under programs that affect his city. The other four cities are participating only in the procedure for chief executive review and comment on Federal programs. A total of $79.5 million in additional Model Cities funds will be available to these 20 cities in fiscal year 1972.

Although planned variations focuses only on the Model Cities program, the Department of Health, Education, and Welfare, the Office of Economic Opportunity, the Department of Labor, the Department of Transportation, and other agencies will implement, to the extent possible, the minimum control and chief executive review and comment procedures in their categorical grant programs in the 20 cities. This implementation will broaden the citywide Model Cities program into a truly compre-

hensive method for the city's chief executive to use in approaching the community development problems of the city.

Annual Arrangements

Prior to the introduction of revenue sharing, an effort is being made to fit Federal categorical aids into locally designed strategies for total community development. Annual arrangements between the Department of Housing and Urban Development and a number of localities are being developed to assure coordination of grant programs and to provide a standard for evaluating specific project applications. This approach seeks to demonstrate that, given a realistic forecast of Federal funding, communities will plan for community development in an effective manner.

Project selection criteria have been or are being developed for various community development grant programs. These criteria will help localities identify projects that are likely to be funded for inclusion in their annual arrangement proposals.

Property Tax Reform

During the period from 1960 to 1970, the burden of the residential property tax more than doubled, from $15 to $34 billion. As a regressive levy, the residential property tax falls most heavily on low-income families, senior citizens, families with fixed incomes, and farmers. Its inequity is compounded by a myriad of assessment formulas.

The bulk of public education support comes from the local property tax. However, in a series of recent court decisions, this tax has been held to be a violation of the constitutional guarantee of equal protection because it makes the quality of a child's education dependent upon the assessed value of property in his school district.

In 1970, anticipating this crisis, President Nixon appointed a Commission on School Finance to investigate the nature of the problem and recommend solutions. Its report will be transmitted early in March 1972. The Departments of Health, Education, and Welfare and the Treasury have been asked to examine the problem as well. In addition, the President has called upon the Advisory Commission on Intergovernmental Relations, a bi-

partisan panel including Members of the Congress, Governors, mayors, and county officials, to study the feasibility of replacing the residential school property tax with a Federal Value Added Tax. Areas of special concentration will include the scope of the taxable base, the optimum income tax credit to avoid regressivity, renter relief, and the maintenance of local control.

[From the New York Times, Mar. 29, 1972]

MISSING: ONE POLICY

During his 3 years as Secretary of Housing and Urban Development, George W. Romney has tried without success to evolve an administration policy for the cities and their suburbs. The other day in Detroit he rhetorically threw up his hands and said the job was too big for the Federal Government. Nothing that Washington could do, he suggested, would halt the terrible slide of inner-city housing into slums.

The problem is certainly too big for this administration; and the responsibility for its nonperformance lies not with Mr. Romney but with President Nixon. Secretary Romney has put forward several initiatives with engaging acronyms, elaborate supporting documentation and ambitious timetables for specific action. Each has been shredded and lost in the White House policy coordinating machine. The input has been sizable; the output zero.

Mr. Romney even has a mausoleum of words to commemorate his own frustration. In the Housing Act of 1970, Congress required that in every even-numbered year the President should submit to Congress a "Report on Urban Growth." Last month President Nixon submitted the first of these reports. If the congressional authors of this idea thought they would get an authorizative summing-up of information and legislative recommendations on behalf of the cities—comparable to the annual reports from the Council of Economic Advisers and the Council on Environmental Quality—they must be as sorely disappointed as Mr. Romney.

This vapid document spends 74 pages explaining that the Federal Government really cannot do much of anything about urban problems or suburban growth. The fragmented and inadequate authority of other levels of government has been amply demonstrated, but the report passes the responsibility back to them: "any consideration of growth issues must recognize that many of these issues fall within the boundaries of State and local governments."

With an air of bustling discovery, the report states: "Ours is a federal system with powers shared between the States and National Government. This system preserves the ability of citizens to have a major voice in determining policies that most directly affect them."

The "major voice," one is tempted to ask, that citizens have in the interstate highway program? Or in the lending policies of the Federal Housing Administration? Or in the administration's impounding of water and sewer grants? Or in Federal Government failure to finance urban mass transit? These are only four of the many Washington decisions to act or not act which have had enormous influence on urban decay and development. No town or city or county can singly cope with the consequences of these Federal decisions.

President Nixon solemnly proclaims in this report that he has no "master plan for directing the multitude of public and private decisions that determine the patterns of progress in modern America."

No one expected him to have a "master plan." But citizens and local officials could reasonably look for some leadership, some guidance on alternatives, and some greater coherence in the Federal Government's own policies. Metropolitan and regional planning are essential, and the financial power of the Federal Government is the best available lever to compel local, county, and State officials to take a broader view of their problems and to cooperate more effectively with one another. Mr. Romney's pessimism notwithstanding, only such Federal leadership can make federalism a viable form of government under complex modern conditions.

There is no mystery about the administration's evasion of this crucial responsibility. President Nixon has political strength in very few of the inner cities. Action on any metropolitanwide problem—housing, transportation, economic development—is sure to upset some voters and some interest groups in the suburbs. If something absolutely has to be said—as in this report on urban growth—then question-begging platitudes are the next safest. The only mystery is why George Romney, a man of integrity and social concern, continues to cooperate in this great vanishing act.

Urban Growth

Back in January 1970, President Nixon was quite eloquent about our urban dilemma. "Between now and the year 2000," he said in his State of the Union Message, "over 100 million children will be born in the United States. Where they grow up—and how—will, more than any one thing, measure the quality of life in the years ahead." He noted that "vast areas of rural America are emptying out of people and of promise." And he conceded that "the violent and decayed central cities of our great metropolitan complexes are the most conspicuous area of failure in American life today."

"I propose," the President said, "That before these problems become insoluble, the Nation develop a national growth policy."

Mr. Nixon was specific as to what he had in mind: "In the future," he said, "decisions as to where to build highways, locate airports, acquire land or sell land, should be made with the clear objective of aiding balanced growth for America. In particular, the Federal Government must be in a position to assist in the building of new cities and the rebuilding of old ones."

Congress listened and acted. In December of the same year, under title VII of the 1970 Housing and Urban Development Act, it declared that Federal programs that affect the location of population, economic growth and the character of urban development "frequently conflict and result in undesirable and costly patterns of urban development which adversely affect the environment and wastefully use our natural resources." The act states "that existing and future programs must be interrelated and coordinated within a system of orderly development and established priorities consistent with a national urban growth policy."

To help formulate such a policy, Congress requires the President to submit a biannual Report on Urban Growth. The first one was due and punctually delivered last February during the famous "week that changed the world" with the President's visit to China. But that was not the only reason why, to our knowledge, only one newspaper, the *Wall Street Journal*, reported it. Another reason is that in a clear reversal of what he had said 2 years earlier, the President—or those who prepared this report for him—now negate the need for a national growth policy. The report, to begin with, drops the word "urban" from its title on the plausible grounds that "rural and urban community development are inseparably linked." It then proceeds to argue, less plausibly, we think, that "no single policy, nor even a single coordinated set of policies, can remedy or even significantly ameliorate all of our ills." We must, after all, the President's second thought continues, respect the country's diversity and pluralism. What with "our unwillingness to trust our destiny to the edicts of any government or the whims of any group," the report says, "there is no place in our country for any policy which arbitrarily dictates where and how our citizens will live and work and spend their leisure time."

The document proceeds to provide some 70 pages of statistics and listings of existing national, state and local programs that bear on the subject of urban growth. There is not a word about how those 100 million children will live, how to check the evacuation of rural America or the plight of our decayed central cities, let alone about where to build highways, locate airports or any other decisions that would aid "balanced growth for America."

This abandonment of a new hope for a new, more comprehensive approach to bringing order and a greater measure of social justice into our urban areas where more than 70 percent of all Americans live, must, first of all, be a keen disappointment to the President's own Secretary of Housing and Urban Development. Mr. Romney has long realized that the problems of the inner city can no longer be solved within the city's boundaries. He has urged the White House to endorse a new approach toward metropolitan area planning to help people out of the ghetto. This program for a "total American living environment," or TACLE, was ignored in the President's vacuous report and has therefore presumably been killed. Mr. Romney publicly aired his disappointment when he said in a recent speech: "We need to make the hard analysis that we don't yet know how to solve this mounting crisis of people in our central cities—but we must find out before it is too late. Failure to do so could result in a fatal national crisis."

The President's first "Report on National Growth" should also be a keen disappointment to Congress whose mandate it largely disregards. So far there has been hardly a murmur of protest on Capitol Hill. Congress has other troubles. And although it voted for urban order, it does not, like the press and the public at large, attach a very high priority to this complex issue. It is much the same, we feel, as it was with other environmental problems before, largely due to the agitation of the young in this country and their "Earth Day," the "establishment" was moved to action on air and water pollution.

Land pollution, due to unguided urban growth, however, is very much part of our environmental crisis. As Mr. Romney says, this must be recognized before it is too late.

COMMENTS ON NATIONAL GROWTH

(By Jay W. Forrester, Germeshausen Professor, Massachusetts Institute of Technology)

The country is rapidly becoming aware of the environmental, economic, and social pressures that are being generated by growth of population and industrial activity. Such pressures develop as growth begins to fill the available natural environment. The stresses from growth do not become conspicuous until growth begins to impinge on its many limits. Growth was able to continue without negative consequences as long as we had an excess of farmland, natural resources, energy, and pollution dissipation capacity. But once these limits began to be approached, pressures started to rise. As growth continues, the pressures from the consequences will increase ever more rapidly.

In response to these pressures created by growth encountering the various national limits, Congress requested and the President submitted a "Report on National Growth 1972." Against a national history in which growth has been strongly encouraged, the report is a break with tradition when it recognizes that many of the Nation's difficulties are benig created by growth. But the report fails to come to grips with the growth issue. The President's report nizes that many of the Nation's difficulties arising from growth can be alleviated without having to control the underlying cause. In so doing, the theme follows the "quantity with quality" viewpoint expressed in the title of an earlier report.

But the issue is no longer "quantity with quality" but instead is "quantity versus quality." As population grows and the production of goods is more and more limited by environmental capacity, the material standard of living will level out and then decline. As population and industrialization expand, crowding will increase, environmental damage will continue, and economic and social aspects of the society will gradually deteriorate. All of this means a declining quality of life as population and industrialization continue to become denser in the available space.

The "Report on National Growth 1972" perhaps moves as far as is now politically feasible toward questioning growth. It does identify the symptoms of growth. It does suggest we must do something about those symptoms. But it does not face the issue of doing something about the causes of the sympoms.

On the matter of growth as the cause of the problems discussed in the report, the report is most misleading. It suggests that growth can continue without detrimental consequences. It suggests that the government must find ways to continue and to encourage growth. This is quite incompatible with the ultimate need to slow and stop growth so that the quality of life can be kept as high as possible.

The report is a transitional document. It identifies the undesirable consequences of growth but does not face the cause itself. One might hope that the next biannual report from the President to Congress would address the question of how long growth can continue. It should also face the inherent tradeoff between quality and quantity. It should examine the time span necessary for moving into an equilibrium in population and industrial activity. It should begin to discuss the quality of life that can still be retained after the unavoidable growth occurs that will take place during the transition time beween now and when equilibrium can be esablished.

[From The Washington Post, Apr. 8, 1972]

SUMMARY [1]

LAND USE AND URBAN GROWTH—Report of the Task Force on Land Use and Urban Growth of the Citizens' Advisory Committee on Environmental Quality

SELECTIVE STRATEGIES FOR DEVELOPMENT AND CONSERVATION

"This is a hopeful report, one which acknowledges the real constraints of the political process in our cities, States, and in the Federal Government, one that does not gloss over intractable problems to minimize difficulties but which attempts to clarify what we know and what we don't know and which identifies a selective strategy for improvement in the way our cities and suburbs and even some remote areas are physically developed and redeveloped.

"Our central concern has been with the use of land as it affects many other conditions of life: the environment we enjoy, how far we must live from our place of work, who are our neighbors and our children's classmates.

"We have looked for the point of leverage where public policy might improve circumstances and free private energies to contribute to, not work against, the broader public interests."

I. THE SITUATION

On the one hand, unrestrained, piecemeal urbanization—supported by a value system that has traditionally equated growth with the good life—has produced too many dreary, environmentally destructive suburbs of a single lifestyle; too many bland, indistinct city centers; extensive mismanagement of the earth's resources; and rising popular discontent. (In some areas that have experienced especially rapid growth many citizens are questioning the desirability of more growth. People concerned about urbanization tend to be against higher density and to sanctify the single-family home. They challenge rezonings that would accommodate more growth, propose studies of optimum population, and approve height limitations. Often they seem to be viewing development itself as the enemy, a kind of pollution that causes congestion and destroyed views. In the 1972 elections, environmental improvement was one of the few policy proposals—perhaps the only proposal—for which citizens in many parts of the country were willing to vote increases in spending. And of 57 candidates for Senate, House, and gubernatorial posts endorsed by the League of Conservation Voters, 43 from 25 States were successful.

On the other hand, the needs of the American population, existing and projected, can be met only through continuing development. (The fertility rate would have to stay at the low ZPG level for about 75 years before population growth would stop. The number of U.S. households is increasing even more sharply than the number of people: from now until 1985 more than 27,000 new households are anticipated every week, equal to a city the size of Kalamazoo, Mich. This increase in the household formation rate is one third greater than that experienced during the decade 1960–70. With higher income have come higher levels of consumption—automobile ownership, recreation, travel, the purchase of bigger homes and even second homes, with the result that people spread out farther over the land. As a consequence, urban land area is increasing far faster than the size of the urban population or the number of urban households.)

II. THE PROBLEM

How shall we organize, control, and coordinate the process of urban development so as to protect what we most value in the environmental cultural and esthetic characteristics of the land while meeting the essential needs of the changing U.S. population for new housing, roads, powerplants, shopping centers, parks, businesses, and industrial facilities?

[1] The complete report will be published by Thomas Y. Crowell Company under the title, *The Use of the Land: A Citizens' Policy Guide to Urban Growth*. A Task Force Report Sponsored by the Rockefeller Brothers Fund. Appr. 384 pages, 5½x8¼. 50 photographs, 12 charts, 6 cartoons. Indexed. Hardcover $10. Paperback $3.95. Prepublication copies will be available late in May.

III. MAIN OBSTACLES TO A SOLUTION

Historically, public opinion has favored development almost irrespective of the cost to the environment. Our laws and institutions, many of which evolved during a time when growth was a national ideal, reflect a prodevelopment bias.

Now, although public opinion is changing, agencies that play by the old rules are increasingly coming under attack, while new rules have yet to be formulated and accepted.

Processes which allow for sensitive accommodations and balance—that assure protection of critical open spaces and historic buildings, but also assure that essential development needs are met—are not yet in effect in most areas.

Many citizens lack confidence in official land use plans. They distrust the way zoning decisions are made.

Landowners expect relatively unlimited rights to develop their property even at the expense of scenic, ecological, and cultural assets treasured by the public

Developers are increasingly having difficulty getting land in sufficient size parcels and with zoning and sewage adequate to permit quality development. The land market is a large part of the problem ; so, in some areas, are antigrowth attitudes.

Most developers lack the opportunity to significantly improve the quality of projects. The small scale of their operations, or the restrictive policies of local government, work against variety protection of important open spaces and other environmental lands, and accommodations of lower income people and mixed life styles in many areas.

Incentives created by the local property tax, and the small size of many local governments, lead them in some growing suburban areas to resist essential urban development, to exclude the poor, and to make decisions that will not raise property taxes or visit change on established residents. The same incentives can sometimes lead them to permit development in the wrong places.

IV. OUR WORKING ASSUMPTIONS

The United States has institutions and policies for solving problems of air and water pollution. To solve the problems of urban growth, we have neither adequate institutional processes nor the necessary legal doctrine.

We have not yet learned to build communities that are environmentally sound and racially open.

We are in a period of great ferment when citizen groups, the courts, a number of State governments, the national administration, and congressional committees have begun to consider fundamental reforms in the way State-local responsibilities for land use control are distributed. At the heart of this ferment is the recognition that States must have the responsibility to control land use decisions that affect the interests of people beyond local boundaries if critical environmental lands are to be protected and development needed by the broader regional population is not to be blocked by local governments.

Public land acquisition cannot, need not, be the whole answer to the problem of open space protection or historic preservation. With private property rights go obligations that society can define and property owners should respect.

It is not enough to think only of conserving what we have. Conservation must be part of a larger effort to create what we want. In a time of massive change, the task must be to maintain a creative balance between the forces of conservation and the forces of development. Only recently and in selected areas where people are applying new high standards to development is this balance becoming possible.

V. OUR CONVICTION

There is no need for people or their governments to accept a future of relatively continuous urbanization in which individuals and communities lose their identities.

Nor is there need to put up with some of the suburban barriers that limit the mobility of people of modest means.

Nor is there need to accept development stretching along the edges of roads and sprawling across scenic hills and valleys, forests, and farms.

There is opportunity, in short, to have urban regions that contain natural beauty, to have new urbanized areas which are more varied and satisfying than those we are familiar with.

VI. OUR APPROACH

Before we came to our conclusions, we surveyed the major reports in land use and urban growth of the past 5 years; we examined significant State and national legislation, pending and enacted; and we conducted field studies in—

1. Florida ("Paradise in Peril"), which attracts 4,300 new residents each week, 550 to Dade County (Miami) alone; which includes three of the fastest growing metropolitan regions in the Nation (south Florida, Tampa-St. Petersburg, and Orlando); which from 1950 to 1969 lost 169,000 acres of estuarine habitat to dredging and filling; which in April 1972 passed a strong set of land and water management laws.
2. Long Island, N.Y., where 2.6 million people are concentrated in two counties fragmented into 110 taxing jurisdictions; which in 10 years (1954–64) lost a full 29 percent of its coastal wetlands; where the NAACP is suing Oyster Bay on charges that rezoning has been used as a tool to keep out the poor and the black; where environmentalists have proliferated since 1969 into more than 100 diverse groups.
3. Colorado, where in November 1972 voters barred the use of city and State funds to support the 1976 Winter Olympic Games, pulling in a welcome mat that had been out for 20 years; where, in Boulder, citizens considered (but defeated) the first referendum in the Nation to limit population size; where longtime U.S. Representative Wayne Aspinall was defeated in the 1972 primary by a law professor running as an environmentalist; where a statewide land use plan is due to be completed by December 1973.
4. California, probably the only State where concerned private citizens have produced a comprehensive plan to provide alternatives to the development proposals of Federal, State, and local agencies; where environmental impact statements are required for significant private as well as public developments; where a powerful independent regulatory agency has been authorized to control all development along the shores of San Francisco Bay; where voters have now empowered the State to take a similar approach to regulating all development along the California coastline and, in most instances, 1,000 yards inland.

VII. CONCLUSIONS

A new mood in American attitudes has emerged that questions traditional assumptions about the desirability of urban development. The motivation is not primarily economic. It appears to be a part of a rising emphasis in human values, on the preservation of natural and cultural characteristics which make for a humanly satisfying living environment.

This new mood represents a force of great energy. On the one hand it is an opportunity; finally, a broad, popular concern for planning and regulating land-use has emerged that can be offset against the one-sided, purely economic values that have characterized much development pressure. On the other hand, it presents a challenge, for it encompasses a range of negative attitudes that are sometimes confused and even hostile to the needs of our society for new development.

Nevertheless, this new mood is the most hopeful portent we see. Although it contains a range of anxieties and discontents, it can be used as a level to achieve the changes in land-use planning and control which will insure a qualitatively different future for us and for American generations to follow.

Spokesmen for poor people sometimes say that environmentalists are more sensitive to the plight of wild ducks than of people. Indeed, the most serious charge is that public policies developed in response to these new attitudes would necessarily impose their heaviest burdens on the least advantaged members of society.

The tensions in the new mood will be better dealt with and understood if it is recognized that the disadvantaged have legitimate needs that only development can meet, and that a measure of urban growth is inevitable in our lifetimes, for the poor and for nearly everyone else. All stand to lose by growth-at-all costs solutions. All can share in the better life which so many Americans by their new awareness and new expectations of managed growth appear to believe is possible.

"No growth" is simply not a viable option for the country in the remainder of this century. The case for more development does not come down simply to demography—to the fact that we must house the people who are already around or whose birth is foreseeable—nor even to any inevitability of economic growth. There is also an ideal involved, of respecting the free choices of Americans to

move in search of a better job or a better life. Mobility has been a traditional road to opportunity in American life. Wholesale growth restrictions, imposed by many communities, could block that road for many who still most want to travel it.

Governmental efforts to divert growth away from metropolitan areas and into lagging areas or to small towns have had little success. The likelihood, in the absence of major changes in attitudes, is for continuation of the metropolitan concentration.

The urban region is a fact of life; the vast majority of Americans will probably continue to live on what is a relatively small area of land, not in cities as we have known them, but in suburbs and exurbs that will be continuous in many areas. The issue is not whether there will be urban regions in the future—that is, regional constellations of urban centers and their hinterlands, as opposed to the concept of single super cities. The issue is what form these urban centers will take and what they will look like.

High density or high-rise living are not the only alternatives to sprawl. Relatively low densities appear fully compatible with increased economic efficiency in the provision of local sewers and roads, and with conservation of substantial open spaces.

"In most instances we have favored the rearrangement of processes, and the redesign of incentives to get the system working for, not against, quality urban development. We have consciously focused less on negative compulsion than on creating positive inducements, less on increasing public expenditures than on making sure that the governmental entity with the proper perspective was the one responsible for dealing with a particular issue, less with tilting the balance toward environmental groups or to developmental interests than in trying to make certain that a newly emerging balance between these forces is maintained."

"Although we recommend a number of measures to inject higher levels of government into the development guidance process, we think it clear that the local base of regulations should be established by local decisions."

VIII. RECOMMENDATIONS

Greenspace

1. In newly urbanizing areas, both recreation and social need will best be served by establishing a public policy that the limited natural supply of prime recreational open spaces, particularly coastal and waterfront areas, should, to the maximum feasible extent, be acquired by Government, preserved, and made publicly accessible.

2. Federal spending for open space acquisition should be maintained at levels commensurate with needs. We see particular merit in continuing to extend the net of parks, seashores, and lakeshores that are owned and managed by the Federal Government itself. States, many of which are currently enjoying budgetary surpluses, should also adjust open space acquisition plans to rising needs, particularly with respect to areas where urban growth is anticipated, and where waterfront land is beginning to appreciate as a result of pollution-control activities.

3. No combination of Federal, State, and local land purchases is likely to acquire all the open spaces that might ideally be enjoyed by the general public. Other techniques to obtain public open space must continue in use, therefore, and efforts to devise effective new techniques must continue.

4. State and local governments should assert and protect often neglected public rights in beaches and other recreation lands. Similarly, the Federal Government should exploit its full range of powers, including its permit authority and public works activities, so as to promote protection, public access and use.

5. Federal estate tax laws should be amended to permit the transfer to the Federal Government of land determined by the Secretary of the Interior to be of national significance, with the fair market value of the land offset against Federal tax liabilities.

6. Governments at all levels should actively solicit open space donations and should facilitate the work of responsible private organizations, such as the Nature Conservancy, by granting them charitable status for real estate tax purposes.

7. Mandatory dedication requirements (imposed on developers) can be an equitable and inexpensive way to provide essential urban open space.

8. In newly developing areas, developers should contribute open space or cash for the purchase of open space, sufficient at least to satisfy the reasonable needs

of the residents of their developments. Local governments should adopt regulations requiring such contributions, preferably in connection with cluster provisions. States should authorize and encourage the adoption of these local regulations, or should adopt similar State regulations.

9. State legislation, as well as local regulations, should assure that adequate public accessways exist before allowing the subdivision or development of private property adjacent to public beaches and waterfronts.

10. To protect public open space against diversion to other public use, States should, at a minimum, provide: (1) That alternatives to the diversion of parklands be formulated with full opportunity for public comment; (2) that any open space taken be replaced by other open space that will, wherever possible, meet similar public needs; (3) that additional procedural protections be established to insure careful evaluation of proposals by one agency to condemn open space under the jurisdiction of another agency; and (4) that methods for determining the value of open space be improved so that any open space may be replaced by land of at least comparable monetary value.

Since it is neither feasible nor acceptable for governments to acquire the vast agricultural and natural areas that ought to be conserved within future urban regions, suitable mechanisms must be found to protect privately held open space. Without such mechanisms, even moderate objectives of open space protection are unlikely to be achieved.

11. The land market, as it operates today, is the principal obstacle to effective protection of private open space.

12. To achieve permanent protection, open spaces should be insulated as completely as possible from the market forces that now inexorably press them into development. One way of accomplishing this objective is for owners of open spaces to give up or sell part of their property rights. Another is for local or State governments to regulate development of open spaces, requiring owners to maintain them as they are.

13. State as well as local governments should establish protective regulations to prevent incompatible development of critical agricultural and environmental areas. Where protected areas are carefully selected as the result of a comprehensive planning process, States should authorize and encourage, in appropriate cases, very low density zoning, including, for example, requirements for 50 or more acres per dwelling unit permitted. Enactment of a national land use policy is urgently recommended as a means to encourage State and local regulation in a framework that adequately recognizes both regional environmental protection and developmental priorities.

14. The Federal Government should encourage open space protection by formulating, mapping, and publicizing a set of advisory national open space classifications for consultation by Federal agencies in the planning of development projects, for use in support of State and local plans and regulations, and for consultation by private land buyers and sellers.

15. Decisions to construct sewers and to provide other public services should be taken only after carefully considering whether these decisions will stimulate or discourage the development of designated open spaces. Plans for the location of federally assisted sewers should conform to a comprehensive land use plan.

16. Governments and charitable organizations have a significant opportunity to preserve open space by providing owners with a just and convenient method of donating urbanization rights and then persuading them to use it. In time, we believe, private ownership of open spaces without urbanization rights should become as commonplace as ownership of land without mineral rights.

17. Incentives are often needed to encourage protection and to backup regulations. Because incentives involve a tradeoff—offering the landowner something in return for a desired response—care must be taken to assure that public benefits are commensurate with public costs.

18. Measures that grant partial relief from real estate taxes on farms in urbanizing areas, in force in about one-half the States, should be reexamined to assure that the public benefit in open space protection warrants the very substantial expense that reduced taxes entail. Provisions that grant reductions in the absence of permanent restrictions should be regarded as halfway measures, justified only when political processes will not accept permanent restrictions.

19. We are persuaded that a mix of techniques, including public acquisition and the purchase of development rights in strategic land parcels (those located along highways, directly adjoining urbanized areas, and along waterfronts) but with primary reliance on federally supported, State-administered, noncompen-

satory regulations can achieve the permanent, low-cost protection of critical open spaces, including buffer zones between urbanized areas.

20. We see the need for a national lands trust to be established either within the Interior Department or by Federal charter and with Federal funding of $200 million annually to be made available on a matching basis with a 75-percent Federal share to assist public bodies, particularly State land-use agencies, in the designation, planning, and conservation of extensive greenspaces in and around major urbanizing areas. The national lands trust would advise on regulatory and acquisition measures and make funds available for acquisition of strategically located lands and partial interests in lands within the greenspaces.

21. A changing attitude toward land, not simply a growing awareness of the importance of stewardship, but a separation of ownership of the land itself from ownership of urbanization rights, is essential.

22. Historically, Americans have thought of urbanization rights as coming from the land itself, "up from the bottom" like minerals or corps. It is equally possible to view them as coming "down from the top," as being created by society and allocated by it to each land parcel. We think it highly likely that in forthcoming decades Americans will gradually abandon the traditional assumption that urbanization rights arise from the land itself. Development potential, on any land and in any community, results largely from the actions of society (especially the construction of public facilities). Other free societies, notably Great Britain, have abandoned the old assumption in their legal systems and now treat development rights as created and allocated to the land by society.

HISTORIC PRESERVATION

23. Historic areas need protection, too. Many communities have important or unusual historic buildings or whole streets and neighborhoods with historic integrity, where the buildings, by their age, design, and scale, form a unit of visual continuity and character. Such areas may already be registered historic districts, as in Charleston, Boston, and Santa Fe, or they may be stylistically varied areas lacking any significant single buildings but forming units of pleasing proportion and providing a sense of the past. Such historic properties are vulnerable to the same threats as open space, and their preservation often poses the same "buy it or lose it" dilemma to local authorities. We see historic districts and buildings benefiting from the same approach and many of the same techniques we recommend for protecting privately owned open space, an approach based primarily on regulation, not purchase.

24. We need broadened classifications for historic areas. Present criteria for listing in the National Register of Historic Places are that the area possess integrity of location, design, setting, materials, workmanship, feeling, and associations and represent a significant and distinguishable entity (even if the components lack individual distinction).

25. The insistence upon integrity of design, feeling, and workmanship discriminates against areas where organic growth has produced a stylistic mixture. Because of the variety in physical structures, these areas can often support a varied rent structure and provide a refreshing diversity of uses and people. We urge that urban neighborhoods characterized by a mix of uses, a vitality of street life, and a physical integrity be given recognition of the national register as "conservation areas."

26. For historic preservation, as for open space protection, the first requisite is a framework for regulation, preferably a statewide system for registration of historic districts and properties and a clear policy favoring preservation. States should enact appropriate legislation to implement the Model State Guidelines for Historic Preservation recommended by the Council of State Governments among its 1972 suggested legislative proposals. Such legislation would establish a State institutional structure for the review and regulation of historic sites, structures, and districts and would enable local governments to take special measures to assure that the integrity of historic areas is protected.

ADAPTING OLD LAWS TO NEW VALUES

27. To protect critical environmental and cultural areas, tough restrictions will have to be placed on the use of privately owned land. These restrictions will be little more than delaying actions if the courts do not uphold them as reasonable measures to protect the public interest, in short, as restrictions that

landowners may fairly be required to bear without payment by the government. The interpretation of the "takings issue" [2] is therefore a crucial matter for future land-use planning and regulatory programs.

28. Many judicial precedents (including some from the U.S. Supreme Court) that date from a time when attitudes toward land, natural processes, and planning were different from those of today. Many judicial precedents are anachronistic now that land is coming to be regarded as a basic natural resource to be protected and conserved and urban development is seen as process needing careful public guidance and control.

29. Ignorance of what higher courts have actually been willing to sustain has created an exaggerated fear that restrictive actions will be declared unconstitutional. Such uncertainty has forestalled countless regulatory actions and induced numerous bad compromises. The popular impression of the takings clause may be even more out of date than some court opinions.

30. Extensive case preparation is necessary to demonstrate the constitutional validity and public benefit of land-use regulations. To facilitate that preparation, the trend toward "environmental divisions" within the offices of State attorneys general and county and municipal attorneys should continue, and attorneys in these divisions are urged to devote a substantial share of their efforts to land-use regulation.

31. Existing nonprofit organizations should be supported and appropriate additional organizations established that will provide government attorneys with the expert testimony, research assistance, and skilled tactical advice needed to prepare for important land-use cases.

32. State and local legislative bodies should continue to adopt regulatory measures which they believe fair and necessary to protect environmental and cultural features. This is important not only directly, to protect these features, but also to help create a climate of opinion in which lawmakers and judges will regard tough, needed restrictions as a proper exercise of governmental power.

33. The courts should presume that any change in existing natural ecosystems is likely to have adverse consequences difficult to foresee. The proponent of the change should therefore be required to demonstrate, as well as possible, the nature and extent of any changes that will result. Such a presumption would build into common law a requirement that the challengers of a governmental regulation prepare a statement similar to the environmental impact statements now required of public agencies under Federal programs.

34. It is time that the U.S. Supreme Court reexamine its earlier precedents that seem to require a balancing of public benefit against land value loss in every case and declare that when the protection of natural, cultural or esthetic resources or the assurance of orderly development are involved, a mere loss in land value will never be justification for invalidating the regulation of land use. Such a reexamination is particularly appropriate considering the consensus that is forming on the need for a national land-use policy.

DEVELOPMENT—SHAPING COMMUNITIES AND NEIGHBORHOODS

35. The mechanisms used to regulate development need improvement. Under most State enabling legislation today, the locality that has a sound planning process can take many of the regulatory steps needed to control development accordingly. To do so, however, the locality must often distort its regulatory process to fit a model established by one-half-century-old enabling legislation. The distortion—particularly the overemphasis on detailed preregulation of the results of the development process and underemphasis of the ongoing processes of policymaking and planning and discretionary decisionmaking that adapt regulation to unfolding reality—sometimes obscures the process even to decisionmakers themselves and often seriously misleads the general public. (We look forward to completion and release of the American Law Institute's Model Land Development Code, which promies to furnish invaluable aid in the modernization of out-of-date State enabling acts.)

36. Even though communities must be more effectively protected against inappropriate development, additional protection is not the most pressing need at the community level. The even greater need is to remold the development process—not only the regulatory process but also the methods by which land and utilities are made available—in order to foster quality development, specifically

[2] The so-called "takings clause" in the fifth amendment to the U.S. Constitution: "* * * nor shall private property be taken for public use, without just compensation."

to enable and encourage developers to operate at larger scales and to use their resulting opportunity to create quality communities.

37. Just as State governments are intervening to provide more protection in some areas, so much they intervene on behalf of more development, particularly the sort that local governments often exclude.

38. For the convenience of all concerned—builders, neighbors, administrators, citizens at large—a convenient, nondiscretionary mechanism must be provided to permit the mass of small projects to proceed without elaborate review—a resembling today's nondiscretionary building permit.

39. For major and unusual development, we believe that the discretionary review process will benefit if it approaches more closely the environmental impact statement process. The great benefits of the process are its focus on proposed development; its consideration of feasible alternatives; and its replacement of the "minimum standards" concept with a concept of seeking among feasible alternatives what is best for the public interest. In the long run the greatest importance of the environmental impact statement process may lie in its establishment of a higher standard of conduct for development agencies, requiring them to publicly evaluate opportunities within a broad spectrum of public objectives.

40. Every element of the regulatory process, including deliberations and advisory recommendations as well as final decisions, should take place at advertised meetings that are open to the general public. To this end, both local and State laws should establish open-meeting requirements applicable to all governmental agencies responsible for land-use regulations.

41. To reduce conflicts of interest, State and local laws should disqualify local and State officials from voting or otherwise participating in any regulatory decision whose outcome could confer financial benefit, or could appear to the public to confer financial benefit, to themselves, their families, or their business or professional associates. All persons having any responsibility for land-use regulation, including elected and appointed officials and employees, should also be required by law to make periodic public disclosures of their financial interests and real estate holdings within the jurisdiction over which they exercise responsibility.

42. Citizen suits appealing from local regulatory decisions should be permitted by any local resident in the public interest, without regard to property ownership or other financial interest in the outcome. Citizen suits to enforce ordinance requirements should also be permitted. Such actions should be subject to appropriate safeguards against premature or frivolous litigation.

43. Fairness alone is not enough. The regulatory process will not merit public trust and respect unless decisions are based on consistent policies and plans. A process of planning and policymaking, far superior to the one now found in most localities, is essential both to earn citizen respect for the regulatory process and to achieve its public objectives.

44. Governments should use all acceptable means to channel as much development as possible into new communities or, to the extent that these are unachieveable, to channel as much development as possible into "growth units" [3] as recommended by the American Institute of Architects. It should be recognized that the success of this policy will be contingent upon the effectiveness of implementing measures in overcoming the several obstacles that now deter developers from operating at larger scales.

45. Loan guarantees now available under title VII of the Urban Growth and New Community Development Act of 1970 should be expanded and made available also for the development of "growth units."

46. The States should establish Government entities, comparable to New York's Urban Development Corp., responsible for assisting and when necessary directly undertaking large-scale projects. These entities should have the full range of powers, including the power of eminent domain, the power to override local land-use regulations, and the power to control the provision of public utilities, whenever necessary to overcome the barriers that now prevent most developers from operating at the larger scales the public interest requires.

47. The development process should, insofar as possible, be shaped so that home buyers and other consumers in the development process perceive continuing livability as the key to profitability. Any potential divergence between livability or quality and profitability should be minimized.

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[3] Of 500 to 3,000 dwelling units, large enough to sustain an elementary school, community center with recreational facilities, convenience shopping, and open space.

48. Important development should be regulated by governments that represent all the people whose lives are likely to be affected by the development, including people who could benefit from it as well as those who could be harmed by it. Where a regulatory decision sugnificantly affects people in more than one locality, this will require more forceful State, regional, or even Federal action than has been usual in the past.

49. Congress should enact a National Land Use Policy Act authorizing Federal funding for States to assert control over land use of State or regional impact and concern. Such legislation should include both incentives in the form of Federal financial aid and sanctions in the form of reductions in Federal highway, airport funds, and open space funds.

50. As part of an overall strategy to increase public acceptance of the exercise of State responsibility for development guidance, the States are encouraged to enact measures that reduce the impact of new development on local property tax rates.

51. State legislation should deprive local governments of the power to establish minimum floor area requirements in excess of a statewide minimum established by statute.

52. The continuing effort of civil-rights groups and other litigants to obtain court decrees invalidating exclusionary regulations are encouraged as essential steps toward achieving the State legislation and administrative action which are ultimately necessary to safeguard fundamental rights.

53. Revisions to existing federal housing programs, particularly those introduced by the Housing Act of 1968, should concentrate on a restructuring of incentives to encourage private investors using these programs to take a long-term interest in their investments.

54. States should enact legislation requiring environmental impact analyses in connection with major actions of State and local governments which significantly affect the environment.

55. As agencies gain experience with the environmental impact statement requirements, they should seek increasingly refined ways to identify the actions and issues that are important enough to warrant such review. Plans, minimum standards, or other criteria that assure some alternative control over the less important actions may prove most acceptable.

56. For powerplants and other critical development, project review procedures should be modified so that disapproval of one development proposal must be accompanied, in the same proceeding, by approval of an alternative or abandonment of the project if need cannot be satisfactorily demonstrated. A much more thorough planning process is needed for this purpose as well as review agencies with larger geographical jurisdiction. Passage of pending powerplant siting legislation would be an important step toward fulfilling this need.

LOT SALES IN RURAL AREAS

There are now about 2.9 million second or recreational homes in America, up from 1.7 million in 1967. It has been estimated that 95,000 second or resort homes were started in 1971, up from an estimated average of 20,000 per year in the 1940's, 40,000 per year in the 1950's, and 75,000 per year in the 1960's. The estimated annual demand for second homes is expected to reach 200,000 by 1980.

Nevertheless, rural lots are being created far faster than second homes. It is estimated that 650,000 recreational lots were sold in 1971. For the Nation as a whole at least six recreational lots were sold that year for each second home started. Much of the excess of lots sales over second home starts is the result of demand artifically inflated by high pressure sales practices. Many buyers are encouraged to think of the lots as an investment or speculation rather than as a building site that they might someday use and enjoy.

57. There should be no effort to discourage the creation of bona fide recreation communities. In the absence of specific wrongs, such as consumer victimization or environmental damage, there is nothing wrong about second homes. The overall goal should be to encourage the creation of livable, ecologically sound recreational communities, and to prevent lot sales where such communities seem unlikely to come into being.

58. Recreational home developments should be required to satisfy the same environmental and land use policy standards that ought to apply to first home

developments. This does not necessarily mean that such communities must have curbings or sidewalks, any more than communities for first homes in every case require such facilities. It does mean that local governments should establish subdivision requirements sufficient to assure that all subdivisions, whether for first homes or second, will attain acceptable development standards and provide adequate public facilities including those for water supply and sewage disposal appropriate to the ecological character of the area in view of the total population that would result if each lot were used. Bonding of any public facilities should be a condition of subdivision approval. Where installation of facilities is to be postponed, substantial sums should be added to the amounts of bonds required to account for future inflation. To assure that needed facilities are guaranteed even in subdivisions in remote rural jurisdictions, the States should also establish regulations requiring these facilities.

59. Every effort should be made to bar lot sales projects in which management and sales practices encourage buyer and seller to disregard the suitability of the project as a long-term place of enjoyment. Particular attention should be given to projects in which the manner of the seller's operation enables him to make substantial profit—or to show a substantial profit on his corporate books—before he installs water supply and sewage disposal facilities and the other rudimentary essentials of community existence.

60. The Congress should amend Federal securities legislation so that the sale of lots—in any project containing more than 50 lots—will, unless all obligations of the seller are performed before any payments by the buyer, be regarded as a securities transaction subject to the prospectus and other requirements of the Securites and Exchange Commission.

61. Federal and State legislation should obligate the sellers of lots—in projects containing 50 or more lots—to guarantee to each buyer that his lot will, for a period of 1 year after the date on which he is scheduled to obtain title, and again for 1 year after the date on which the contract obligates the seller to complete all improvements, be fit for construction of a dwelling—or for any commercial or industrial uses specified by the seller in the sales contract. Fitness for use should be defined, by statute or regulation, to include piped-in water supply, the available of lawful sewage disposal facilities, and safety elements (e.g. land not subject to flooding, free from danger of mud or rockslides). The warranty should be unwaivable, and breach of warranty should entitle the buyer to return of all his payments with interest and damages up to the date of breach.

62. The Securities and Exchange Commission should require statements describing development programs planned by land sales corporations, including pertinent information about the types of community facilities to be provided, the dates at which they are scheduled for completion, and who is to construct them.

63. Federal and State laws requiring full disclosure of lot sales information to protect lot buyers should be amended so that projects containing more than 50 lots are covered, irrespective of the acreage contained in each lot. The present right of a buyer to reconsider his decision up to 48 hours after purchase should be extended to 30 days, with present statutory exceptions eliminated.

ABOUT THE TASK FORCE

The task force on land use and urban growth was formed in the summer of 1972 by the Citizens' Advisory Committee on Environmental Quality at the suggestion of its then chairman, Laurance S. Rockefeller. Its work has been supported entirely by grants from the Rockefeller Brothers Fund.

Although the task force has the status of a private organization, the Citizens' Advisory Committee on Environmental Quality reports to both the President and to the Council on Environmental Quality.

The task force is made up of three members of the citizens' committee, and nine others drawn from the fields of banking, State and local government, civil rights and minority affairs, citizen action, university administration, business, new community development, planning, and law. William K. Reilly, lawyer, planner, and senior staff member on leave from the Council on Environmental Quality, has served as staff director.

Task Force members:

Mr. Laurance S. Rockefeller, Chairman, New York, New York.

Dr. Paul N. Ylvisaker, Deputy Chairman, Dean, Graduate School of Education,

Harvard University, Cambridge, Massachusetts.
Hon. John F. Collins, Consulting Professor of Urban Affairs, Massachusetts Institute of Technology, Cambridge, Massachusetts.
Mr. John R. Crowley, Chairman, Colorado Land Use Commission, Denver, Colorado.
Commissioner Henry L. Diamond, New York State Department of Environmental Conservation, Albany, New York.
Mr. Walter E. Hoadley, Executive Vice President and Chief Economist, Bank of America National Trust & Savings Association, San Francisco, California.
Mr. A. Wesley Hodge, Lawyer, Hodge, Dahlgren & Hillis, Seattle, Washington.
Mr. Vernon E. Jordan, Jr., Executive Director, National Urban League, New York, New York.
Mrs. Virginia Nugent, Chairman, National Land Use Committee, League of Women Voters, Washington, D.C.
Mr. John R. Price, Jr., Vice President, Manufacturers Hanover Trust, New York, New York.
Mr. James W. Rouse, Chairman of the Board, Rouse Company, Columbia, Maryland.
Hon. Pete Wilson, Mayor of San Diego, San Diego, California.

THE WHITE HOUSE,
Washington, May 31, 1972.

From: John D. Ehrlichman.
Subject: National Growth Policy.

There is continuing and growing interest in the subject of national growth policy. In the short run, we can expect issues to arise in the coming months and in the formulation of the fiscal year 1974 budget which reflect the administration's conception of national growth policy. The overall framework is defined in this year's report, and we must continue to define and refine this issue.

In addition, we should begin processes now which will lead to a firm basis for the 1974 growth report.

With these two objectives in mind, I would like your detailed and thoughtful consideration of the specific questions in the attached paper. This document is designed to do the following:

1. To identify areas where agreement among agencies exists and can be fairly said to rest on a firm basis.
2. To identify areas of disagreement among agencies based on different interpretations of trends, facts, studies, et cetera.
3. To identify important areas where studies or evidence have not yet been developed.

This year's national growth policy study demonstrates a need for a new approach which should be reflected, as appropriate, in agency staffing. Would you please contact my office within 10 days with the name of the senior policy officer who will have overall responsibility for this task.

May I please have your response by July 30, 1972. We will review these responses with the President before deciding on further steps.

SCOPE OF WORK—NATIONAL GROWTH POLICY

In order to develop a more firmly based position on national growth and national growth policy, the Federal establishment must do much more than it has done in the past to:

Define "national growth policy";
Define the Federal role in national growth policy;
Examine present Federal policies toward national growth;
Examine present programs with national growth impact;
Examine related topics of importance to the process; and pattern of growth

In each of these areas, a number of specific questions must be answered.

A. Define "National Growth Policy"

1. (*a*) Is there a consensus in the literature on what "national growth policy" means? (*b*) If there is a consensus, what is it and who are the groups and individuals responsible for it?

2. (*a*) How far have the "growth experts" gotten in specifying the content of "balanced and orderly growth" in real terms (the definition stressed by the Congress)?

3. (*a*) What evidence suggests that the development of a national growth policy is possible? (*b*) Are there examples or studies indicating in operational terms what a national growth policy could or could not do? (*c*) Can we draw lessons from the experience of other countries?

4. (*a*) Is it possible to limit the definition or concerns of national growth policy in such a way as to make it operationally effective and useful? (*b*) Specifically, what kinds of institutions, actions, processes or procedures at the Federal level directly flow from having stated a national growth policy? (*c*) What would be the form of stating a national growth policy?

5. (*a*) Would it be wise to attempt to develop and utilize a national growth policy? (*b*) What are the political pluses and minuses of stating such a policy? (*c*) To what extent would a national growth policy be subject to economic, political, and social constraints which would make the policy irrelevant?

6. (*a*) Are there studies which show the relationship of a national growth policy to other national policies of interest such as economic stability at full employment, industrial planning, tax policies, population growth and movement, environmental and resources planning, et cetera? (*b*) Who, if anyone or any institution, has, at this point in time, sufficient technical expertise and politically viable organizations to relate these policies? (*c*) If no such vehicles for achieving interrelationships exist, what options exist for filling the gap?

7. (*a*) Is there any reliable estimate of alternative futures for the country in the absence of a national growth policy? (*b*) Can we say with any certainty what the impact of the presence or absence of a policy would be?

8. (*a*) Do we know enough about how the general public (not the "growth experts") wants the country to look in the future and, more importantly, what the public is willing to sacrifice in order to achieve it? (*b*) If the answer is "Yes," what is the source of our information? (*c*) If the answer is "No," how do we find out?

9. (*a*) What evidence is there to show either a public consensus, need for, or an overriding necessity for the formulation of certain national growth policy objectives? (*b*) Are there growth objectives which can safely be said to have widespread or universal support which are not being promoted by present Federal policy? (*c*) Do these include the stated title VII objectives?

B. Define the Federal Role in National Growth Policy

1. (*a*) What guidelines or concept should serve as the basis for Federal action to achieve and utilize a national growth policy?

2. (*a*) How do we define the national interest—how do we balance the relative weights of economic, social and other considerations? (*b*) What studies or evidence tend to support various alternatives?

3. (*a*) What is the appropriate forum for formulating the Federal role in national growth policy? (*b*) What precisely did Congress mean in enacting the title VII language establishing the national growth policy report and objective?

4. (*a*) To what extent should popular present concerns such as population growth and the environment indicate a need for a Federal role? (*b*) To what extent should less direct but equally pressing concerns such as trade deficits, industrial productivity and the market economy influence Federal policy toward growth?

5. (*a*) To what extent should a national growth policy attempt to achieve welfare and social goals? (*b*) Specifically, which goals warrant more Federal promotion? (*c*) Is there evidence to suggest that the Federal role must give more weight to welfare considerations than State and local governments give?

6. (*a*) Is there a consensus on whether or not the Federal Government should be concerned with the location of activity in this country? (*b*) To what extent should the Federal Government be concerned with the future "map" of the country? (*c*) Is it possible to have a growth policy which does not specify where growth should occur or what appropriate actions are needed to achieve locational growth objectives? (*d*) How does one distinguish between a "locational" growth policy and any other?

7. (*a*) What are the political pressures at the Federal level which can be expected to bear on the formulation of a national growth policy? (*b*) How do these pressures affect Congress and the executive branch? (*c*) What are the primary interests, both bureaucratic and nongovernmental, which will affect the way national growth policies are formulated? (*d*) Can these pressures be offset against each other in order to preserve the integrity of whatever policy is adopted?

8. (*a*) What does the evidence suggest about the feasibility of coordinating Federal activities to implement a national growth policy? (*b*) What has been our experience to date with past or similar efforts?

9. (*a*) To what extent is "disorderly growth" a national growth policy concern? (*b*) Is there a national consensus on what constitutes disorder? (*c*) If so, what are the specific features? (*d*) Are we imposing higher standards on metropolitan development? (*e*) What processes of transportation and land development could be changed to accommodate higher standards? (*f*) What Federal operational policies does this imply?

C. Examining Present Federal National Growth Policies

1. (*a*) What evidence exists to indicate how much leverage (potential or real) Federal policies and programs have on the growth process?

2. (*a*) What do we get for the $35 to $40 billion now spent annually on Federal grants to States and localities? (*b*) Is there evidence to suggest that the leverage which this money possesses has been inadequately used in the past? (*c*) How could it be increased? (*d*) Is there evidence to suggest that these Federal funds have little or no leverage effect?

3. (*a*) Which Federal directives, if any, expressed in legislation conflict with one another in influencing growth? (*b*) To what extent to conflicting directives cancel each other?

4. (*a*) Are there administrative policies and Presidential directives which are either internally inconsistent or conflict with congressional directives, as far as growth is concerned? (*b*) What weight must be attached to these various policies? (*c*) To what extent are they self-enforcing and self-implementing, as opposed to being dependent upon forceful advocacy? (*d*) To what extent are these directives location specific? (*e*) Are there studies to show their location impacts and effects?

5. (*a*) Do we have enough information to be able to identify distortions in free (or competitive) market behavior which result from Federal policies? (*b*) Is it possible to quantify the effects of these distortions in any realistic way? (*c*) Are there analytical techniques which can be used in the absence of hard evidence to estimate the efficiency losses of these distortions? (*d*) Are there studies which have used these techniques to estimate these losses? (*e*) Is it possible to estimate the political costs associated with eliminating those policies with a large negative impact?

6. (*a*) Are there policies of the Federal Government which are not related to programs but more directly related to the economic, social and cultural "environment" which express national growth policies? (*b*) If so, what are they and are there estimates of the impact of these nonprogrammatic policies on national growth? (*c*) In the absence of quantitative estimates, are there at least estimates of the direction in which these nonprogrammatic policies impact?

7. (*a*) To what extent does a consensus exist that there is now a general lack of Federal leadership in developing priorities and policies for national growth? (*b*) Are there operational roles consistent with conclusions of section B above which the Federal Government could adopt which would achieve the objectives implied in these criticisms? (*c*) If not, are there adequate and appropriate alternative ways of achieving the same objective, such as inducements to State or local action or private action?

D. Examining Present Programs With National Growth Impact

1. (*a*) Has an analysis been made of the relative impacts of Federal programs on the rate and location of national growth? (*b*) What significant assumptions about "national growth policy" and the Federal role are implicit in these measures and in the identification of such Federal program?

2. (*a*) What consensus exists on how the location of jobs should influence housing programs, manpower programs, transportation programs, et cetera? (*b*) To what extent is population dispersal and concentration taken into account in these programs? (*c*) In what concrete ways do program management decisions reflect these concerns? (*d*) Could a national growth policy be reflected in these program decisions? (*e*) How could program managers, with a much narrower perspective, be influenced to support a much broader objective in making decisions? (*f*) In what form would the directive have to come (that is, Presidential Executive order, legislation, informal administrative practice) in order to have any effect?

3. (*a*) Is there an urban fiscal crisis? (*b*) How is it manifested? (*c*) To what extent does the presence or absence of an urban fiscal crisis determine Federal funding policies? (*d*) Is there evidence to suggest that in the absence of a fiscal crisis, revenue sharing, welfare reform, property tax reform, et cetera, would represent inappropriate uses of tax dollars? (*e*) What Federal urban programs,

would be superfluous if either the fiscal crisis were shown not to exist or Federal tax transfer policies were instituted? (*f*) What Federal urban programs would be particularly effective if the fiscal crisis were shown to exist?

4. (*a*) Is there an analysis to show the impact of the Federal minimum wage on where jobs are located and who holds them? (*b*) Is this something that needs to dealt with in Federal legislation? (*c*) What are the possibilities and prospects for various alternative forms of minimum wage legislation that might minimize any adverse impact on growth that is found to exist?

5. (*a*) What does available evidence suggest the effect fo urban renewal on central cities has been? (*b*) What does the evidence indicate about the relative priority of urban renewal at the local level? (*c*) Is the HUD conclusion that the program has failed supported by public or professional consensus? (*d*) If so, what policy changes are warranted?

6. (*a*) Is there now a Federal policy or directive on preserving and expanding the stock of housing? (*b*) What are the appropriate criteria to be used in defining the Federal role and developing appropriate programs? (*c*) Is there at this point a sufficient evidence and analysis to support alternative Federal housing programs?

7. (*a*) What is the appropriate Federal role in evaluating the effects of metropolitan "balkanization"? (*b*) Assuming adverse effects can be shown, what should be the Federal role in alleviating them? (*c*) Is a rethinking of Federal participation in encouraging metropolitan government indicated? (*d*) If so, what studies and demonstrations, if any, should be undertaken?

E. Examine Related Topics of Importance

1. (*a*) Is it possible now to estimate quantitatively the fiscal needs of the cities? (*b*) What evidence, for example, supports New York City's estimate that it requires $50 billion in investment over the next 10 years? (*c*) Are there consistent standards of service delivery and amenity which can be used to objectively quantify urban needs?

2. (*a*) What is the impact of urban employee wage demands on the fiscal position of the cities? (*b*) Is there evidence to indicate excessive vulnerability? (*c*) What organizational or procedural steps, particularly Federal ones, could be taken to deal with this problem?

3. (*a*) What is the impact of local property taxes on the location of employment, residential construction, et cetera? (*b*) To what extent does this question bear on Federal policies?

4. (*a*) Are there indications that the reduction in migration during the last decade is permanent? (*b*) What factors, if present, would restimulate long-range migration, particularly of blacks? (*c*) Are there appropriate Federal policies which could be developed to encourage or inhibit such migration? (*d*) Should such policies be adopted?

5. (*a*) What are the objectives of a growth center strategy as now employed by USDA, DOT, and the Appalachian Regional Commission? (*b*) Are these objectives consistent? (*c*) Are the criteria consistent? (*d*) Is there a need for federally consistent criteria or should this be left to State determination? (*e*) Could the Federal Government set down meaningful criteria? (*f*) If so, how?

6. (*a*) What are the effects of present Federal policies on racial and economic segregation policies? (*b*) Can these be quantified, either in terms of persons affected or economic costs to society? (*c*) What are the effects of racial segregation on Federal programs?

7. (*a*) To what extent should the Federal Government concern itself with the efficiency of local government services? (*b*) Is there a Federal interest in insuring that Federal tax transfer payments are wisely spent? (*c*) Does this extend to development of new forms of urban technology and services or merely to a "technology transfer" role between cities through advisory and consultative mechanisms?

8. (*a*) What are the effects of present court decisions and other policies relating to equality of public services within metropolitan areas and, perhaps, States? (*b*) Are there distortions caused by current methods of financing and providing Federal services which are either of Federal origin or concern? (*c*) Should the Federal Government attempt to even out the distribution of services (regardless of its responsibility for existing distortions)?

9. (*a*) To what extent should patterns of growth within metropolitan areas, especially as they affect the location of jobs, the decay of central cities, and increasing segregation, be taken into account in future Federal program devel-

opment? (*b*) Is there sufficient evidence to indicate how the Federal Government can get a handle on these problems?

10. (*a*) Is there a Federal interest in the harmonization and equalization of property tax rates as between classes of taxpayers? (*b*) Do, for example, business concerns pay their way in terms of tax revenues? (*c*) What costs are imposed on society by classes of taxpayers which are not taken into account in local tax sources and procedures? (*d*) Is there evidence to substantiate claims of inequitable income redistribution inherent in such tax policies?